MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF AN APPLICATION BY CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES FOR THE PURPOSE OF THE PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Honourable Mr. Justice Berger, Commissioner)

Yellowknife, N.W.T.

April 10, 1975

PROCEEDINGS AT INQUIRY

VOLUME XXVII

APPEARANCES:

Mr. Ian G. Scott, Q.C. Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Inquiry;
Mr. Pierre Genest, Q.C. Mr. Jack Marshall, Mr. Darryl Carter and Mr. John Steeves	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs, Q.C. Mr. Alan Hollingworth	for Foothills Pipelines Ltd.;
Mr. Russell Anthony, and Prof. Alastair Lucas	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton	For Northwest Territories Indian Brotherhood and Metis Association of the Northwest Territories;
Miss Lesley Lane	for Inuit Tapirisat of Canada and, The Committee for Original Peoples' Entitlement;
Mr. Ron Veale and Mr. Allen Lueck,	for Council for Yukon Indians
Mr. Carson H. Templeton,	for Environm ental Protection Board;
Mr. David Reesor,	for Northwest Territories Association of Municipalities;
Mr. Murray Sigler,	for Northwest Territories Chamber of Commerce.

I N D E X

Yellowknife, N.W.T.
April 10, 1975.

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. GENEST: Mr. Commissioner, before Mr. Scott resumes, Dr. Clark has a correction I believe to make to some evidence that he gave yesterday about drill holes. He's concerned that he may have given an incorrect impression.

DR. CLARK: Yes, we were discussing Swimming Point, Mr. Commissioner. After the discussion, I had the opportunity to have a close look at the drawings to which Mr. Scott and Dr. Hollingshead were referring, and I found that all of the drill holes that had been drilled are in fact shown on that cross-section, and are extracted from a report entitled "Investigation of Major River Crossings in the Northwest Territories" by R.M. Hardy and Associates, for Northern Engineering, and it was dated June, 1974 and its number 257 on the list of reports.

DR. HOLLINGSHEAD: Excuse me, Mr. Commissioner. If I could have just another 30 seconds to clarify the record with regard to the calculation of these volumes that we were thrashing around yesterday.

MR. GENEST: That's the volumes of --

DR. HOLLINGSHEAD: The volumes

of the trench at the Point Separation crossing, -- to calculate those volumes, one would simply multiply the average cross-sectional area of the trench. Multiply that by the length of the trench and divide it by 27 to convert it to cubic yards, and I beleve that for the preliminary designs as it stands, the downstream crossing which was the first, the figure was about three-quarters of a million cubic yards and for the upstream, or the second crossing, it would be of the order of one million cubic yards, for a total of one and three-quarter million cubic yards.

THE COMMISSIONER: That was Point Separation, the two trenches at Point Separation?

DR. HOLLINGSHEAD: The twin crossings at Point Separation, sir.

MR. SCOTT: Mr. Commissioner, could I tender as an Exhibit, this peat bog drawing? As number --

THE COMMISSIONER: Speckled bog --

MR. SCOTT: I'm sorry.

(SPECKLED BOG COMPLEX DRAWING MARKED EXHIBIT NUMBER 95)

JOHN IVOR CLARK
GARRY WOOD HOLLINGSHEAD
EDWARD CHARLES McROBERTS
WILLIAM ALEXANDER SLUSARCHUK
NORMAN REUBEN MORGENSTERN
RICHARD H. COOPER
R.M. HARDY
GUY LESLIE WILLIAMS, Resumed:

CROSS-EXAMINATION BY MR. SCOTT, CONTINUED:

Q Dr. Slusarchuk, yesterday we dealt with the Calgary test site, and I'd like to deal briefly with the other three. Are you the person to whom I should direct the questions, or is that -- is it Mr. Williams or -- or shall we just try you and --

A Okay, sir.

Q -- if we need assistance or advice or advice from anybody?

Now, I take it as a matter of general principle, that it was considered by the company, or the predecessor company necessary to establish Arctic test facilities, to provide precedent or experience in the design, construction and perhaps to a limited extent, the operation of buried chilled line in permafrost terrain. Would that be correct?

WITNESS WILLIAMS:

A Yes, I think that is one of the reasons I gave in that slide presentation of why the test facility was constructed.

Q I take it that that is the substantial reason, that in fact there is no other

reason? That's why you have the test sites?

A Would you repeat the reason again, please?

Q The reason is the reason that you have, the purpose being to provide some precedent or experience in the operation of this type of line in the terrain?

A Yes, I think broadly speaking, that covers the more detailed reasons that I suggested.

Q And the Prudhoe Bay test-site, I understand, reviewing your evidence, that construction commenced there about March of 1971.

A I think that is correct. I don't recall giving evidence to that effect. None of the panel were involved in the construction of the Prudhoe Bay test site.

Q Well, see reference I think is page 28 of the application; and I understand that construction commenced at Sans Sault in January of 1971, preceded by preliminary site investigation in June of 1970.

A Yes, actually the road construction at Sans Sault started in July, late July of 1970.

Q And that construction at Norman Wells was commenced in April or early in 1971.

A I think that's correct.

Q Now I take it from those dates that it is reasonably obvious that the decision on the location of the sites must have been made in 1970 or earlier.

A That is certainly correct with respect to Sans Sault.

Q Yes, well what about Prudhoe Bay, construction commenced there in March of 1971. Wouldn't it be a fair inference that the selection of that site had occurred in 1970?

A I really just don't know, Mr. Scott.

Q And with respect to Norman Wells, construction was under way there in April of 1971, wouldn't you agree with me that the site was probably selected in 1970?

A Again I'm not sure, but it could be late '70 or early '71.

WITNESS HARDY: I have a little bit of background on that, Mr. Scott, that might be useful as far as the Norman Wells site is concerned. The group that planned that, I don't think, were organized in the summer of 1970. The site -- the first dealings I had with them was the fall of 1970, and they were just organized.

So that it was the organization or the planning of the test-site at Norman Wells was done on a very rapid program, almost a crash program. There were two competing groups, you see, and the second group that put in the test facility at Norman Wells was trying to catch up time-wise.

Q So would you agree then that the site at Norman Wells was probably selected in late 1970?

A I would agree with that, yes.

Q Well now, I take it, Mr. Williams, that in 1970 the major source of information available to the owners was the Mackenzie

Valley Pipeline drill-holes of which there were a considerable number?

WITNESS WILLIAMS: Yes, that drill-hole information was mainly in that report by Ripley - Klowne done for the Mackenzie Valley which the Northwest project participated in, and received that information.

Q Yes, and in that report, I think, as I understand it, dealt with some 750 drill-holes, approximately.

A I don't recall but that sounds reasonable.

Q And that virtually none of them were on the route, and some of them were some distance away from the route.

A Which route, sir?

Q The ultimate route of the pipeline, the ultimate route that the applicant has chosen.

A I would think there were some that were fairly close to the present route on the east side of the river. Certainly there were some on the west side of the river. There were quite a few on the interior route, and I think there were a few along the Yukon Coast, not too many but there were some along the east side of the river.

Q Would you agree with me that the majority of them were some distance from the ultimate route?

A I would take your word for it probably.

MR. GENEST: Is that your information?

MR. SCOTT: That's my information.

MR. GENEST: I think we can take that; if we dispute it,I think we can accept that kind of statement.

MR. SCOTT: Yes.

Q And with respect to those drill holes, I understand that you had available to you the bore hole logs.

A Yes sir.

Q Yes, but that there was no personal knowledge on the part of the applicant or Northern Engineering of any of those drill holes.

A We did not participate in the taking of field data collection of that information, no.

Q Well, I put it to you that that was the -- apart from inspection by sight-- that was the information that you had at hand that enabled you to select these three Arctic test sites.

A Again I can only speak for the Sans Sault site. We had that information and we had terrain typing information by Dr. Mollard, and we had reconnaissance trips along the valley, inspection trips at sites along the proposed route.

Q Yes. I take it that another company made the selection at Prudhoe Bay and at Norman Wells.

A Certainly Northern Engineering were not involved in the selection of those sites.

Q So you have no way of knowing the basis on which they were selected of your own knowledge within your company.

A That is right, only what we read in the reports.

Q Well, Mr. Williams, at least with respect to Sans Sault, of which you do have personal knowledge, I suggest to you that Dr. Mollard's terrain typing was not available in 1970 at the time the selection at Sans Sault was made. Does that refresh your memory?

A Oh, I think he had -- I'm pretty sure, I'm certain he had done a fair bit of terrain typing in the Mackenzie Valley at that time, and I think he had some high level photography, high level government photography encompassing the Sans Sault site.

Q Well, let me just --

WITNESS HARDY: I am positive from my own connection with the selection of that site and the input that R.M. Hardy & Associates had that Dr. Mollard was a participant in discussions on the selection of the Sans Sault Rapids test facility.

Q Well perhaps Dr. Mollard should be allowed to speak for himself, and I refer you, Mr. Commissioner, to his evidence in Volume 18 at page 2058, which I will read beginning at Question 23 -- at question on line 23.

"I am concerned about that," and the previous pages deal with the question of when the terrain typing was done. "I'm concerned about that, doctor, because the canned evidence, if I can use that expression, reveals that a route was given to the consultants at a certain period of time and I presume that a route would not have been selected without your terrain analysis maps.

"Now, does that help you to tell me when you got in to the hands of Northern Engineering, the terrain analysis map that deals with this corridor in substance?

"A Well, I really cannot tell you the date because we did it over such a period of time and I think the major part of it was done in '72, though. That would be my recollection, '72, '73".

Now I put it to you, Mr. Williams, that if Dr. Mollard is correct, that the substantial part of his work was done in '72-73, it would follow that you would not have available that work at the time when the Sans Sault route -- I'm sorry, when the Sans Sault site was selected?

WITNESS WILLIAMS: I'm sure that the work that Dr. Mollard is referring to

there is the work along the route that was adopted after the merger of the Gas Arctic System and the Northwest Project, which is on the east side of the Mackenzie River. Prior to that, Dr. Mollard had done considerable terrain typing along other routes for the Northwest Project, and Mackenzie Valley Oil Pipeline.

Part of that work was -- the work for Northwest Project in 1970 and '71, was along the west side of the Mackenzie River. Part of the work that Dr. Mollard did in that same period was for Mackenzie Valley Pipeline, which was -- which part of the route was along the east side of the river. He did this work jointly for formerly Northwest Project and Mackenzie Valley. We shared the costs of the photography, and Dr. Mollard's services.

Q Just so we'll have it, is it your position that Dr. Mollard's recollection is faulty, or that he is mistaken in his dates?

A No, he was referring to the route that was selected after merger, the one for Canadian Arctic Gas.

Q Well, what precisely did you have from Dr. Mollard in 1970, according to your recollection?

A For the Northwest Project we had terrain typing on photography. In Alaska, in the interior route, in Canada, along the coastal plain in Canada, and the -- and along the west side of the Mackenzie River down to Camsell Bend, and from there to a point about -- terminating about Cold Lake,

Alberta.

Q And I take it that since that time you have continued to make proposed alterations or alternatives to the route, leading to the two alternatives or quasi-alternatives that were put before us close to the opening of this inquiry, the Fort Simpson route change and the cross-delta considered proposal, if I may call it that?

A We have considered many alternatives since that time. Originally, the two major alternatives were the coastal route and the interior route, but we are constantly looking to try to improve the routing.

Q The point I am making, Mr. Williams, is that I understand from the evidence, the canned evidence, and what has been said here, that these test facilities are of considerable importance? You don't disagree with that, do you?

A No sir.

Q And they're relied upon, by the applicant, as proof in part, that the conceptual theories advanced will work out?

A Yes, sir.

Q And indeed in the canned evidence at page 8, the answer is

"The test facility sites were carefully selected to provide permafrost and terrain conditions which were representative of considerable lengths of the proposed route, as it was realized that the pipeline would

encounter terrain units and conditions different from those that could be selected at any given site, the site conditions selected tended towards the more difficult end of the possible range".

Now, I suggest to you that that statement goes a little far, doesn't it?

A No sir, I agree with that statement, with respect to Sans Sault, of which I have particular knowledge.

Q Well, what about the other two?

A Well I know, for instance, that the Norman Wells site is located in Dr. Mollard's terrain unit GLB which we considered to be one of the more difficult terrain units along the route.

Q Well let me suggest to you that at the time the selections were made, the applicant had very little knowledge indeed of the precise terrain typing or of the route that it would ultimately advance?

A Certainly with respect to Sans Sault, when the test site was selected, we were considering a route along the west side of the Mackenzie River, yes.

Q And what happened is even after you moved to the east side, you've changed almost half of it, or are close to changing half of it, since then?

A Yes, but we are in very similar terrain units as defined by Dr. Mollard, whether you are on the east side or the west side of the river.

Q Well, is it really intended to advance the proposition that in 1970, these three sites were selected with any knowledge of what the ultimate route would be?

A We had routes selected there that are not the route as filed, but I don't think that's a major factor in selecting test sites.

Q How can the applicant say that the sites were selected to the more difficult end of the possible range when it wasn't known where the route was going to go? To begin with, you end up on the wrong side of the river.

A I think I just said a few minutes ago or a few seconds ago that the terrain units that the sites are in are typical of the more difficult range of soil conditions along the route as forwarded in the exhibit.

Q Well, I put it to you respectfully that a much more accurate statement of the selection process is contained in the interim report,"Arctic Test Facility, Mountain River, Northwest-Territory", at page 10-2.

MR. GENEST: Mountain River?

MR. SCOTT: Mountain River is Sans Sault, as I understand it;

Q And it says at the top of that page:

> "The Mountain River site was the most favorable alternative relative to accessibility, climate and general terrain conditions."

That those three factors are the factors that led to its selection.

A Yes, I don't think that's inconsistent.

Q Well, there is nothing in there, and I put it to you there was nothing in your

mind about selecting a site that tended toward the more difficult end of the possible range, as you've said in the canned evidence.

A In the slide presentation I think I indicated that before that site was constructed, we went into that area and did some soils drilling, some very extensive soils drilling. We spent the best part of three weeks in and around that area doing soils drilling, and we found the material that we were looking for that represented the more difficult end of the terrain and soils condition that any pipeline along the Mackenzie Valley corridor would encounter.

Q Let me just wrap it by saying, Mr. Williams, that I suggest to you that you didn't know in 1970 whether it was the most difficult end of the possible range.

A I don't think I agree with that, sir.

Q All right.

A The other day you made reference to the fact that some or all of the Sans Sault site was located in the terrain unit D.L. and I don't think this is correct, and I probably would like to take a few minutes to pursue that to show why we think that that is the more difficult end of the scale.

Q Well, if Mr. Genest has no objection, I don't want to impede you.

After all it is important, it seems to me, that everything depends on these test sites.

THE COMMISSIONER: Would you just repeat the point you're now going to seek to develop?

WITNESS WILLIAMS: Well, last week there was a reference made, Mr. Commissioner, to the fact that the Sans Sault test site is located in a terrain unit described as Dr. Mollard -- I'm sorry, I said D.L., I meant H.T., high terrace.

THE COMMISSIONER: Yes, Mr. Anthony raised that.

A Mr. Scott, I'm sorry.

Q I thought it was Mr. Anthony that raised it, but anyway go on.

A Yes, it was Mr. Anthony and at the time Mr. Scott made the observation that this represents less than 1% of the route. I have prepared a few view graphs in this regard and if you are interested, sir, I would like to show them to demonstrate that the soil conditions in fact at Sans Sault are in a difficult soil condition. But it will take a few minutes to set up the view graph.

THE COMMISSIONER: Go ahead. You go ahead and Mr. Scott can pursue other matters, perhaps.

MR. SCOTT: I take it I'm not being timed if Mr. Williams wants to do it now I have no objection. I can go on or --

A I could come back to it

any time.

MR. SCOTT: It seems to me it might be a subject for re-examination.

THE COMMISSIONER: Yes. Well, we'll come back to it later today.

MR. GENEST: Another day, sir?

THE COMMISSIONER: Well, it doesn't matter to me. Just so long as Mr. Williams is given this opportunity, I'd like to see the graphs.

MR. GENEST: It just seemed to me that if Mr. Scott is going to pursue an attack on the conclusions we've drawn from the Sans Sault test facility as being unrepresentative or being of limited value because of the limitations he described, it might be well for the Inquiry to have that in mind before he pursues his line of examination.

MR. SCOTT: I don't care, Mr. Commissioner, if my friend wants to get this evidence before you now or in re-examination, it's a matter of complete indifference to me.

THE COMMISSIONER: Well, let's see it now then and then we don't have to spend any more time discussing it when we will see it.

WITNESS WILLIAMS: In the slide presentation that I gave I think I mentioned that Dr. Mollard selected five potential sites for a test facility, and that this was his first selection, Now, within this area of the general Sans Sault area, here is the Mackenzie River, the Mountain River, the

Sans Sault Rapids themselves are in this area, and this report, I think, is early 1970, Mr. Scott. This is a copy of a drawing from that report of Dr. Mollard's. Within the Sans Sault area he has outlined with the numbers and the dashed lines five potential sites, and he's pointed out in his report that there are thermokarst, the TK, the thermokarst features, the eroding banks along the Mountain River, there is of course along the Mackenzie -- it's close to the Mackenzie which was one requirement. There is potential off-loading sites here , thaw features, so this was in his report that he gave to us to explore for the specific soil conditions, and in the report I think -- and somewhere here he suggests what kind of soil we might find, the prevalent soil type is expected to be mainly stratified silt, fine sand, made grade from sands at the base of the section to silt at the top and certainly we consider silts with reasonably high ice content to be one of the difficult terrain units that must be crossed.

So that was the basis for his original recommendations, and this --

Q If I could interrupt, Mr. Williams, I am not quite clear, because I haven't looked as to whether that report of Dr. Mollard, from which that slide is taken, is listed. Perhaps Mr. Marshall could let me have the number of it in due course, not now, or if it's not listed, produce it.

A I looked for it in Calgary, and I couldn't find it. The map that I had was extracted, that I had at Sans Sault with me when we were doing the test drilling at the site.

If we don't have it I'm sure Dr. Mollard does, but I didn't ask him for a copy and I'm not sure whether it's listed.

Q Well Mr. Williams, you've got another free weekend coming up, you can have a look for it.

A This particular map is taken out of a report on sub-surface conditions, Mountain River area by R.M. Hardy and Associates, and it's dated August the 31st, 1971. And it was the only one that I could find that covered the test site areas, showing the terrain units as described by Dr. Mollard, and certainly from this very small scale map, you would say that the test site is located in the terrain unit H.T., high terrace, but remember that this is at a scale of about 4 miles to the inch, 4 miles to the inch, and you see a boundary line here between the H.T. and the D.L., plus the G.L.B.

And in the slides, as I have them upstairs, I can get them if you want, but I think you'll remember that we showed in the slide that there was a bit of relief along -- and I should have shown that in the previous one. I should have pointed that out that Dr. Mollard shows what he calls escarpments, generally old and moderately sloping. The escarpment dropping off to the Mackenzie River in this direction, but also a smaller escarpment dropping here, and also here, and I think he has described it as being possibly an old channel between the Carcajou River here and the Mountain River here.

And getting back to this one, and I talked to Dr. Mollard about this on the telephone, and he suggested this division between H.T. and D.L. plus G.L.B. is in fact, along that escarpment that you saw that I pointed out in the slides of the Sans Sault test site. And certainly the camp, the fuel facilities that you saw, the main equipment facilities, are located on top of this terrace, but part of the active test facilities themselves, the buried pipeline, are below the terrace. In fact, in the D.L. plus G.L.B.

And if you -- there's quite a widely circulated volume by Dr. Mollard. I think it's Volume II of his series that was prepared jointly for Mackenzie Valley and the Northwest Project, where he outlines the stratigraphy of these various terrain units, and I think he explained quite fully when he was here, that these terrain units refer mainly to the geological history of the material; how it was

deposited or how it came into being, and these columnar stratigraphy illustrations are taken from that volume.

Q Mr. Commissioner, if I could interrupt just for a moment, I don't want to impede this evidence except to observe that it's clearly evidence that Dr. Mollard should have given, and there will be submissions in due course as to its weight, but I don't want to impede it from being heard.

THE COMMISSIONER: Carry on, Mr. Williams.

WITNESS WILLIAMS: I would have been very pleased for Dr. Mollard to give this. I'm sorry it didn't come up while he was here. He could do it much better than I am able to do it.

But anyway, out of his book you can see that with the terrain unit H.D., he suggests zero to five feet of peat overlaying organic silts and clays, overlying gravels and sands, and his stratigraphy of the unit D.L. you can see is very similar, one to four and a half feet of peat overlying organic silts and clays. The difference here is that this is finer material at the lower depths, sand, whereas it shows some gravel. But at the bottom of the trench, the depth that we're interested in, the 10 feet, they're very similar.

And if you go to the G.L.B. unit, also illustrated in his Volume II, you can see that there's not that much significant difference to one

to five feet of peat overlaying silts and clays. That overlaying sands and gravel till .

We just have a couple of view graphs here to show some of the actual drill hole data. The column on the left is taken from the Sans Sault site, it's active section number 4. It's drill hole B-90 and you can see that there is about an inch and a half -- I'm sorry, one and a half feet of peat, overlaying some organic material, including ice, overlaying silt, sandy silt, silty sand, with fairly high ice contents. These two are shown differently, this is a visual ice content which is high. This is a drill hole along the pipeline route, on the east side of the river near Mile 507 in terrain unit GLB. Again, you can see the two feet of peat overlaying clays, overlaying silts. High ice content certainly in the peat layer, fairly high ice content in the silt, but generally the drill hole logs are not that widely separated.

Again, this is a comparison of a drill hole number B-I35 in active test section number 3 at Sans Sault. In this case, we have four and a half feet of peat, overlaying organic silt and clays, and again, of course, the ice content in the peat is very high, but in this case, in the silt it's in this particular area it's not so low.

And here we have a drill hole in terrain unit DL, near mile 424 on the east side of the river, with again, four and a half feet of peat overlaying silts with some sand. Again, not

that much difference.

Again on the left is drill hole data from section 1, thats the active -- I'm sorry, that's the buried section, the cycling section, where we change the temperature periodically, section 1, drill hole B-203, organic clay for 2 1/2 feet, and then silts, medium plastic, very high ice content, this particular drill hole encountered ice and I think I illustrated what the ditch wall looked like in this section. There were various large pieces of ice encountered in the trench wall, and along the pipeline route at Milepost 192, 300-odd miles from the previous one I showed. Again we have 2 1/2 feet of peat overlaying clay with high ice content, and organic material in the clay. Again it's shown to illustrate that the drill hole data at Sans Sault and the information we got from logging the ditch illustrates that this is similar to what we consider to be the difficult soil type along the pipeline route.

MR. ANTHONY: Before Mr. Scott proceeds, I'd like to first of all, because this evidence has just come out at this stage and I haven't had an opportunity of either viewing it or preparing any questions on it, and I am advised that there are some very serious questions to be asked, I would like perhaps to discuss with Mr. Genest or with the Commissioner at a later stage to have Dr. Mollard perhaps return and comment on Mr. Williams' statements of the similarities of terrain classification which Dr. Mollard has classified as being different, and I think that

could possibly be done at a later stage when we've all had a chance to look more closely at it. But I wonder if I could ask one question of Mr. Williams now with respect to, I think, the very first statement he said about selection, and about Dr. Mollard's selection. I think he said something to the effect of, in his first graph, that Dr. Mollard had picked the Sans Sault location as a first choice and I was wondering, was he saying that Sans Sault was selected by Dr. Mollard as a first choice for a test facility, or was the particular location at Sans Sault selected by Dr. Mollard? Did he say, "If you're going to be at Sans Sault, here is the place to go?" Or did he say, "If you're going to set up a test facility along the Mackenzie, Sans Sault is the general location"?

WITNESS WILLIAMS: Can I refer to the evidence that I read into the hearing before presenting that slide information? Oh, you don't have the -- let me just check and we'll get it verbatim.

MR. ANTHONY: I think that point is being addressed. I have the -- in case anyone else was struggling with the same problem. The discussion about the characterization of a high terrace and the percentage along the route was in Volume 22, March 20th, at page 2560, in that area for people that want to make a reference, but I don't think that this particular question I directed was dealt with at that stage. I was hoping that it would be a fairly simply question as to whether the location was selected,

or just a part at Sans Sault was selected by Dr. Mollard.

A What I said earlier last week was that we asked Dr. Mollard to look at the aerial photographs along the route and suggest some potential test sites. He selected five areas as potential sites. His first choice, because it had a wide variety of conditions within a small area, was the Sans Sault area. In addition to that, he had -- he selected some test sites many miles from Sans Sault, but within the Sans Sault area he selected what he thought were five smaller areas to look at. This, in fact, we did. We went in and spent two to three weeks drilling until we found the soil conditions that we were looking for. Does that answer the question, Mr. Anthony?

MR. ANTHONY: Well, perhaps there is just one supplemental thing. Those five suggested locations were all at Sans Sault, according to what you've presented now, and I was wondering --

A No, I'm sorry. I left the wrong impression. He selected five locations that were separated by -- hundreds of miles along the -- I think as far as 100 miles spacing along the Mackenzie River.

MR. ANTHONY: I see, and then he also suggested the particular location at Sans Sault as the best of the five at Sans Sault? As a secondary decision.

A No sir.

Q Sorry.

A He selected five general areas of which Sans Sault was one.

Q And the exact location at Sans Sault was decided --

A By myself.

MR. ANTHONY: Fine, thank you.

A On the view graph that I showed earlier, within the Sans Sault area he outlined five sub-areas for exploration. We looked at some of them, not all of them. When we found the soil and ice condition that we thought was representative of the more difficult end of the scale along the Mackenzie Valley with respect to soil types, we stopped looking and I laid out the actual facilities that resulted at Sans Sault.

MR. ANTHONY: I think I best leave that at this stage. The more serious questions perhaps should wait until I've had a chance to look at it. Thank you.

MR. SCOTT: Well, Mr. Commissioner, I'm glad to find things aren't much different here than in Toronto, that Mr. Genest has brought with him the technique of utilizing a question as a launching pad to deal with the evidence of the previous panel.

MR. GENEST: Well, sir, I don'T want to prolong this by lawyers' argument, but it seemed to me that this is an important subject, that if I had raised it in re-examination my friends would have been on their feet asking to go into it, and

better early than late.

MR. SCOTT: I don't complain about it. I just feel that the answer might have been given if I'd asked Mr. Williams his name.

Q I take it, Mr. Williams, the effect of what you are saying about Dr. Mollard's testimony on panel 1 is that while he has devised three terrain types, H.T., D.L., and G.L.B., that's correct, he's got those three terrain types on his maps and defined.

A Yes sir.

Q And I take it that what you're saying is that in your judgment D.L. and G.L.B. are in fact a refinement of H.T. and very similar.

A No, I'm saying that the terrain types that he gives refer to the geological history and within those units there can be similarities.

Q In short, aren't you saying that D.L. and G.L.B., in your judgment, are very close to H.T.?

A The stratigraphy for that particular physiographic division would indicate that they are quite similar, yes sir.

Q Well, Dr. Mollard will be glad to know that because he won't have to use so many letters to describe the terrain the next time; but I'm going to ask you one specific question. It was observed that on some of the holes that you

illustrated that H.T. was underlain by gravel at the 10-foot level, isn't that correct?

A It could be. It shows that -- I think if you read that column the way it was intended, that maybe in 10 to 15% of it would be underlain -- would have gravel at the 10-foot level.

Q Yes, and gravel is not traditionally regarded as a frost-susceptible soil.

A No sir.

Q And that D.L. and G.L.B. on the other hand were lain -- were underlain at depths below the pipe by silty sand.

A Yes sir.

Q And that is a terrain type of soil that is traditionally regarded as much more frost-susceptible.

A This Sans Sault site was in permafrost, Mr. Scott. We weren't looking for frost-susceptible soil at that time, we were more interested in what happened to the permafrost with construction and pipeline operation under various temperature operating conditions.

Q I think that's no doubt correct, but my observation about the type of soil is also correct, is it not?

A Yes, that's right, but I think Dr. Slusarchuk has illustrated pretty well yesterday that if it's in a frozen condition there's not a serious frost-heave problem.

Q But apart from that, you don't quarrel with Mr. Anthony's observation that the answer he obtained that if HT is the appropriate designation, about one percent, or a very modest percentage of the line is found under that terrain type?

A Yes, sir. But the active sections at Sans Sault are not all located in HT.

Q No, but it's substantially HT, isn't it?

A No, sir.

Q Well, we can look at the map and judge.

A I think three out of the four buried sections are not in HT; one of the buried sections partially.

Q Well just if I can go back where we were, Mr. Williams, with respect to Sans Sault, is it your position that when this site was chosen, it was known with assurance that it represented the more difficult end of the possible range? To use the words of the canned evidence.

A Yes sir, that was my determination from observing the drill holes that were done to prove up the site.

Q Now, I take it that you have provided in your report on the sites, the objectives of the tests that were conducted at each site? I don't want to go over them, but there is a report that lists a series of objectives, and I take

it that that is a complete list of the objectives of each of the projects?

A Can I have a reference?

Q It's Chapter 8B135, Arctic Test Facilities. I don't want to go through it, I just want to have your assurance that the objectives set out for each of the test sites in that paragraph, were in fact the limit of the objectives that -- for which these test sites were designed?

MR. GENEST: Mr. Scott, what are you reading from?

MR. SCOTT: The location, design and capacity of facilities, Section 8. At page 21.

A I don't think the objectives are limited to page 21, are they, Mr. Scott?

Q They follow through in the succeeding pages.

A Page 18 and continue on.

Q The chapter, as I recall it, is set up in such a fashion that there is a heading objective and then some comment or report on how that tested out, and there are a series of objectives. I just want to be sure that you've listed there all the objectives of the test sites, for which they were designed.

A Oh I'm not sure, I would guess it's reasonably close. I --

Q All right, that's --

A -- haven't read it lately.

Q Well now, I don't know

whether you or Dr. Slusarchuk should answer this, but I take it that at some of the test sites, measurement was made of the surface settlement of the land?

A Yes, sir.

Q Was that done at all three?

A I think so.

Q Well now, were comparisons also made between the predictive surface settlement and the measured surface settlement?

WITNESS SLUSARCHUK:

A At Norman Wells, they had cold test sections and warm test sections, and I recall from their report that they did make such comparisons for the warm test sections.

Q Well, is there any documentation in support of those comparisons? Weve been unable to find any. Perhaps I can take you to figures 5 through 13 in Section 8B137 of the application. And that, Mr. Commissioner, is a series of figures that are described depth of thaw and surface settlement at a number of locations at the test sites. And I want to know if those are predicted amounts or actual amounts, on the route.

These are -- I'm sorry, I misstated it. These are figures that show the settlement on Sections of the route, and I want to know if these are predicted figures or if they are actual figures.

A Is this in Section 8B13.7?

Q Yes.

A Okay, it's not in the section on test facilities, now this is in the geothermal section.

Q Yes.

A Those are predicted ones, sir.

Q Well, have any of them been measured, actually?

A These were examples that we gave, sir, and they were predicted measurements here.

Q Yes, but what I'm concerned about is of what value are they if there is no information as to the extent to which your predicted values and the actual values match?

A I don't recall making such a study myself sir, on that, and other than the one with this company that they made at the hot test section, I'm not sure that any others have been made.

Q Well what I'm asking, and perhaps Mr. Genest can deal with it later, is there any documentation, report or study which indicates by measurement, by actual measurement, the extent to which your predictions of surface settlements are realistic?

A I think we can outline or produce documents for you, sir, out of the public literature here, that would document measurements that have actually been made at test sites, and we have followed similar procedures.

Q But I take it, just to have it clear, that there has -- as far as you know now, and maybe there is some other information that you can produce later, but there has been no comparison of actual settlements at any of those locations with your predicted figures?

WITNESS MORGENSTERN:

A: May I comment here? That may not be so. One of the major objectives of some of the Mackenzie Valley buried oil pipeline activities was to evaluate the prediction of settlement due to thaw with observation , and papers have been published and another is in press on that type of activity.

Q Well that's so, as I understand, Dr. Morgenstern, for one limited test site at Inuvik. Now what I'm concerned about, is there any documentation that shows that with respect to this project and the places where it is going to run,that your ability to predict the thaw settlement has been proved by doing actual measurements, to compare?

WITNESS SLUSARCHUK:

A Other than that warm berm sections, I am not familiar with reports that specifically deal with that item, sir.

Q Well what's the use of them, then?

A The use of?

Q Of the predictions?

A It is not a novel idea, sir,

to thaw soil that has 20 percent ice in it and assume that it is going to settle 20 percent when the ice thaws and melts and flows away. This has been discussed for quite some time in the open literature that has been documented in various places, and it is to that body of literature that I was referring to, and it is that sort of knowledge that I brought along with me when I came to this project, and perhaps that's one reason I never thought of prime concern to try and set up some documentation on it.

I was involved with that project that Dr. Morgenstern was previously referring to with Mackenzie Valley Pipeline through my relationship with the National Research Council, and it did not seem to me to be a pressing item at that time.

Q Well, now let me turn to another matter. It's our understanding that both buried and elevated pipeline sections were experimented with at Sans Sault, is that correct?

WITNESS WILLIAMS: Yes, Sir.

THE COMMISSIONER:

Excuse me, Mr. Scott. Just before we leave that, Dr. Slusarchuk, so that there is no misunderstanding here, you're saying that if you have a good idea what the ice content is, in the soil, then you can predict the extent of surface settlement of the land owing to thaw and it doesn't get you anywhere to carry out measurement at some later time to test the accuracy of your prediction.

The important thing is to know how much ice there is in the frozen soil, is that your position?

WITNESS SLUSARCHUK:

A That's correct, sir, and a great number of these sort of comparisons have been made in the past and documented in the open literature, and that is why we did not undertake to do it ourselves. We thought that that was more or less an acceptable, or more or less a routine sort of method of doing it.

Q I take it that in short the proposition is that you are prepared to assume that that could be done with assurance?

A Yes, sir.

Q Well now, turning to the buried and elevated pipeline sections that were experimented with at Sans Sault, is there a report available on the results with respect to the elevated pipeline sections?

WITNESS WILLIAMS:

A No sir, nothing really beyond the mention of it perhaps in that red volume, that interim report at Sans Sault.

Q Well, may I ask why that part of the experiment was not reported on?

A There wasn't really a great deal to report on. The elevated section was put in to look at in case there was a remote possibility that we might have to go to that mode of construction. We did observe it through the life of

the test and really very little happened, except the coating deterioration that I referred to in the slide show, so there wasn't a great deal to report on.

Q I put to you, Mr. Williams, that before you conducted that experiment you had already decided, or your client had decided as a matter of policy, that there was going to be no elevated sections to the pipeline.

A No sir.

Q All right, well then wouldn't it be useful, if I can respectfully say so, to have a report on what you found out about the elevated experiment?

A I think since the test site has been constructed we have decided that it's desirable to have no or as little as possible elevated pipeline. As I say, we did observe it, and nothing of any significance happened. I suppose a 2-page report could be written, we just didn't think it was necessary or worthwhile.

Q Well, I take it that you're not saying that there will be no elevated sections of this pipeline.

A No sir, I think we said that there will be some around compressor stations.

Q Well, are the results of your studies, if not in report form, in some other form available?

A No, just in peoples' heads. Except for some elevation measurements on file, that was done in the course of taking the survey around the site, which was done at fairly frequent

intervals.

Q Well, I put it to you that there is some experience with elevated pipelines in other parts of the world,is there not?

A Yes sir.

Q Yes, and therefore one considering the construction of a pipeline of this type in Arctic terrain would look to precedents in other parts of the world.

A Yes, we have certainly read the Russian literature.

Q And those precedents in Russia, in part in Alaska, and in China, are elevated pipelines.

A The one being constructed in Alaska, a considerable portion is going to be elevated, yes. As I say, we have read the -- quite a bit of the Russian publication.

Q And are you familiar with the 800 mile Chinese elevated pipeline?

A No sir, I am not.

Q All right.

MR. GENEST: Are you?

MR. SCOTT: Yes. I can refer the Inquiry to a report in, of all places, the "Victoria Times", of Monday, January 13 of 1975, which refers to a -- ironically the report is an Associated Press Report out of Tokyo but it reports on the construction of an 800-mile pipeline in China

in Arctic terrain.

MR. GENEST: I hope that one wouldn't have the same status as a publication by--

MR. SCOTT: I shouldn't say "Arctic terrain", it doesn't say that. It crosses rivers at 260 places, railways at 10 places, and highways at more than -- and then the copy is blotted but there is room for one figure and then there are two zeros, so it's anything from 100 to 999 places. I'm sorry, 900 places, and it crosses frozen earth, marshes and rapids.

Q I put it to you, not to be facetious, Mr. Williams, that the experience outside Canada has generally speaking been with elevated pipelines in Arctic or sub-Arctic terrain.

A This is excluding the one in China, is it?

Q We'll leave that out for the moment. I don't want to ask you about a pipeline with which you're not familiar, at least in theory.

A Yes sir, I understand that quite a few of the Russian pipelines in Arctic terrain are elevated.

Q And because of that experience, anybody approaching the question of building a pipeline as a matter of principle would want to thoroughly consider what other people have done, especially when they're the only people.

A Yes sir.

Q Yes, and with that in mind you not only went -- your people not only consulted with the Russians but you built a portion of the test facility to deal with the elevated pipeline option.

A Yes, we went to great expense to have some of the Russian publications translated.

Q And you went to some expense to build a facility that would deal with the elevated pipeline option.

A Yes sir.

Q Well now, can you tell me really the reason why the public is not afforded an opportunity to examine the results of your experience when it approaches this question of how the pipeline in Canada's Arctic will be built?

A I think we'd be pleased to write a 2-page report on the elevated section at Sans Sault for someone who is interested. All I can say is what I've said before, is that after the construction at Sans Sault we came to the conclusion that very little of this system should be elevated and what happened at Sans Sault didn't teach us a great deal and we didn't consider it worthwhile reporting; but it could be done.

Q Well, I wouldn't ask you to write a report which you have in advance determined is only going to be two pages, and tell us nothing.

But I presume that as you've done an extensive analysis of the other alternatives, and have done some analysis of this alternative, that it would be helpful to have the results so others can compare the options. However, if it's not available, its not available.

Now I'm led to believe that two of the seven test sections at Sans Sault were placed in slopes to check their performance, is that correct?

A Yes sir.

Q Yes, and at one at least there was a large shallow slide that occurred. Is that correct?

A Yes.

Q And at the other there was an erosion problem of some consequence.

A Yes sir, not great consequence, I wouldn't say. A minor consequence, yes.

Q Now I take it, therefore, I concede these were only experiments, but they were not experiments that were totally successful in that context. Things happened that were unfortunate.

A In hindsight, sir, I think what happened could have been predicted. In the slide presentation for the sake of brevity, I didn't deal with the inactive sites. If you are going to explore it, I would like to give a little bit of history of that situation.

Q Well, I'm simply going to

ask you if there is any more detailed information than is made available in the Sans Sault report on the nature of these experiments and analysis for their failures? Or is the Sans Sault Report, which is already a document, all we're going to get on that subject?

A I think Dr. McRoberts has examined the failure on the Mountain River near Sans Sault and could probably discuss it. I don't think he has written a report on it.

Q We'll be asking generally about slope problems a little later, but what I want to understand is, is there a more detailed analysis available of those two problems than the one that is contained in the Sans Sault Report?

A No, there isn't right now. We do plan some additional work on that Mountain River situation.

Q I take it that this kind of experiment was not done at any of the other facilities?

A I am fairly certain that there was one inactive section installed at Prudhoe Bay. Oh, I'm sorry, I was referring to inactive sections in general. The one at Prudhoe Bay was certainly, there was no slope there and the inactive section was on the flat.

Q So that the Sans Sault experience, as far as test facilities are concerned, related to slopes, is what you have.

A Yes sir.

THE COMMISSIONER: Well, just so I am not left out of the picture, what -- was there a slope failure at Sans Sault?

A Yes sir, there was.

Q On the Mountain River?

A On the bank of the Mountain River.

Q And was there an inactive buried pipe involved in the failure?

A Yes sir, there was. Shall I give a brief description of those inactive sections at Sans Sault?

THE COMMISSIONER: Yes, I will just ask Mr. Scott how he feels about that.

MR. SCOTT: I don't object to that.

THE COMMISSIONER: Yes, go ahead. I've been to Sans Sault, I think I've seen the sections active and inactive. I've seen the Mountain River and the Mackenzie River, so I don't think that we need a slide, I think you can tell me.

A Yes sir. In the planning of the test facility at Sans Sault, we were wondering what would happen to buried pipe during the period of construction and the time that it came into operation when chilled gas was in the line to stabilize the soil around the pipe, so we installed six 80-foot lengths of pipe in various situations within a, I think,

a two or three-mile radius of the main facility at Sans Sault. We selected the areas to try to represent the most difficult situations we could find within that radius. Three of them were located in flat areas, mostly adjacent to thermokarst ponds that would become flooded to various extents during the spring breakup, spring thaw. One was located on the bank of the Mountain River, one was on the bank of the Mackenzie River, and one was constructed across a small stream just a few feet wide, and one of them in particular south of the -- about a mile and a half south of the test site, was flooded by ~~as~~ much as two feet of water in the spring following the installation, and we were extremely surprised that the pipe did not float out of the ground. We have some theories on why it didn't, but by all that's right it should have floated out.

THE COMMISSIONER: That was an 80 foot length?

A That was an 80 foot length that was capped on the ends so that no water could enter the pipe, and risers were placed on the pipe so that we could take survey shots on it to see what was happening. And with the exception of the one on the bank of the Mountain River, none of them moved that we could determine with our surveyor's level.

The one on the Mountain River, we excavated a trench about, I think it was 150 or 200 feet long, and of course we just had 80 feet of pipe to put into the trench. We put it in the lower portion of the trench, and then we backfilled the whole thing.

The wall of the trench in that area was particularly interesting, the ice in the old cracks was particularly interesting, but in the backfill and restoration, we took no standard precautions that would be done even in southern pipeline construction. We just backfilled it and compacted it as best we could, and we didn't install any cross-berms to control the drainage, or any ditch plugs. None of these things that Dr. Clark has referred to in the last week, we just backfilled it and left it, which we thought was subjecting the pipe to a bad situation.

And it did stand up through the spring break-up, but during a heavy rain in the summer, water was channelled down the ditch, and

it did pond around the pipe, and the slope failure occurred. But I want to emphasize that no good construction practices were followed in the backfill and restoration of the section. In fact, the top hundred feet or so of this ditch that was excavated had had no pipe in it, and because it was fairly high ice content soil, during the spring and summer thaw, a fair bit of subsidance along the ditch line did occur.

And with respect to how the slide was initiated and what-not, I think Dr. McRoberts would be pleased to speak about it.

WITNESS MCROBERTS:

A I would be quite pleased sir, if that suits you, right now.

THE COMMISSIONER: If there is anything to add to what Mr. Williams has said, just so we understand what did occur and the circumstances under which it did. Just suit yourself.

A Yes, Mr. Commissioner, I have three slides that you might be -- that illustrate the feature that we were talking about.

THE COMMISSIONER: Well, let's adjourn for coffee and then look at those slides briefly when we come back. Would that be all right?

(PROCEEDINGS ADJOURNED)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT:

Q Mr. Williams is out for a moment, I understand from Mr. Marshall,but I don't see any reason perhaps why we can't proceed with what Dr. McRoberts is going to do.

THE COMMISSIONER: Before you go ahead, Dr. McRoberts, since it appears we will be sitting this afternoon, to accommodate the typists, we'll take a break from 12:30 to 2:30 for lunch.

MR. SCOTT: Yes, sir. I presume Mr. Williams is out getting some more slides.

WITNESS MCROBERTS:

A What I would like to do, Mr. Commissioner, is just quickly present a couple of slides to illustrate what happened in active site number 2 at the Sans Sault test facility, and make a couple of brief comments as to the various factors that actually caused failure.

Can I have the first slide, please? This picture was taken in the fall of 1974, after four complete thaw seasons, that is to say, the pipe was installed in 1970 -- in the winter of 1970, and there was four complete thaw seasons between when the pipe was installed and when this picture was taken. This is on towards the end of the year.

The Mountain River is down here, and the Mackenzie is over here, and the main test facility is down in this direction, and we are about a mile and a half away. We're on the banks here of the Mountain River, and it's difficult to see in this

picture, perhaps we can have the next one.

We're looking now into the bank, and the bank of the Mountain River, or the top of the bank is about through here, and the pipe is installed down about an eight degree slope here, and that's to say, eight degrees of inclination, and then a 16 degree slope down to here. There's a heavy tree cover that be about here, and that marks the beginning of the slope, so there's two components of the slope; an 8 degree section and a 16 degree section.

THE COMMISSIONER: So the pipe was on a gradient as if you were going to cross the river?

A That's correct. Yes.

Now, let me get to that. To the pipe,/there was a ditch down from here down to here, and because we had so much pipe at the time or the people that were responsible -- Mr. Williams had so much pipe at the time, he installed pipe in this deeper section of the slope here to here, and no pipe was installed up here. Just as background.

Now as you can see, this is what's developed by 1970, the end of 1974, and the failure occurred on the steeper 16 degree segment of the slope.

Can I have the next slide, please?

This picture is taken past the break in slope. There's an 8 degree slope that comes down behind here, and we are now on the steeper

section. This is the same gentleman that appeared for scale in one of Mr. Williams' slides earlier. He comes up to about here on me. Just to put the scale in perspective, it is a four foot diameter -- excuse me four inch? Sorry, a 42 inch diameter pipe.

You can see the extent of the slope failure and the erosion that has occurred, out to here and through to here. You can see there is a very silty clay soil and in fact in some cases, there are still organics left, there is still backfill remaining over the pipe. This -- as I emphasized, the way the pipe looked after four complete thaw seasons.

Can we just back up one, please?

There are several factors that contributed to this failure. The first one is the method of construction that was followed. As Mr. Williams pointed out, the practice that the pipe was put in using very crude techniques, in fact this surface was cleared by bulldozer, which would not -- which was certainly one practice that we would not follow in any slope like this, in fact, we would clear it by hand, and that certainly had an influence. The pipe was installed and the backfill was put in in a more or less random manner, with some attempt at compaction.

In a slope like this of this angle and that terrain type I certainly would not recommend that you would use native backfill. We would, in fact, be using more select material for backfill under conditions like that. Furthermore there was no, as Mr. Williams pointed out, no drainage and erosion control features put in at the site that Dr. Clark talked about, there was no sack breakers, there was no chevron type of breakers to shed the water. There was also, and perhaps it's obvious, no slope instability as to slope preventative remedial measures placed.

The next -- so the first contributing factor was the method of construction and the way not only in the method in which the drain was cleared and the pipe installed, but also the state in which the slope was left in the wintertime.

The second contributory factor was there was a period of very heavy rain, a soaking rain for about seven days. We know this because we operated a full-scale meteorological station at Sans Sault Camp, and we measured the amount of rain over the period, and when the storm and the fog and the low visibility conditions lifted the site was visited the same day when the bad weather lifted, and the people that visited it commented that there was a considerable slope erosion had occurred. At that time the pipe was not exposed and the instability that had occurred was certainly not to the extent that you see here. It was much, much lesser extent. Since then, of

course, the failure, the slope instability has proceeded sideways but you'll notice it's remained in the 16 degrees component of the slope and not in the 8 degree.

The third contributory -- now in regards to the heavy rain, certainly we had the feeling that if we had had a properly designed drainage and erosion control measure, then that would have obviated perhaps completely prevented any problems occurring. However, there are three other factors.

The next factor is ice content. This slope in through here from the observations made in the ditch wall and from the bore holes that were put in, certainly indicate that below a depth of about three feet there was very high ice content soils and that certainly contributed to failure. Once we -- the failure occurred about June or July, my memory doesn't serve me, I'm just relying on records, I wasn't associated with the project at that time, but it was in June or July of '71 that the failure occurred. THere had been a fair development of the active layer by that time.

The fourth contributing factory in regards to the onset of failure is soil type. The soil that's encountered here is very fine-grained silty clay, and if you took the same soil type and had it in a completely unfrozen state, a thawed state, had never been frozen, on a slope where one might experience you'd get a lot of rain, let's say around Vancouver, and you had it on a 16-degree

slope, and you soaked it and it rained and you got this soil completely saturated with the kind of material that we encounter here, the kind of strength it had, the strength properties of that material we'd expect failure. So in one sense the failure that occurred had nothing to do with the fact that it was a permafrost slope, from purely geotechnical considerations, and the flow conditions in the soil with the degree of saturation, one would expect failure.

The fifth contributory factor would be the very thin layer of peat that's found in through here, the peat is much thicker up on top. Along the slope and down through here the peat is very thin. Looking at the banks along the Mountain River for maybe a length of a distance of 20 to 25 miles or whatever, until the Mountain River gets right into the mountains, is just one continuous band of landslides, and this slope in through here, was historically a slope failure of some form, and because of that the peat, as you understand, had not had a long time to develop, there is very thin, maybe three to four inches of peat, and therefore the rate of thaw of the material and the depth of thaw would be enhanced because the peat cover was very thin. In situations such as this, and keeping in mind the ice content, keeping in mind the soil type, the type of preventative slope stabilization methods that we propose to use would inhibit failure so that if we used that, if we choose, as we would in a condition

as severe as this to stabilize the slope and to provide erosion control measures, nothing would occur. We choose -- at least my understanding of the matter is that while we have had some of our revegetation people have been mad keen to get in here and see if we could stop it, and I'm sure we could stop it if we choose to, we have taken the view that we would like to - it is a test section and we appreciated that when we got in here we had a pretty darn good chance of failure, we couldn't expect anything else outside the banks from the Mountain River all the way up to where the Mountain River goes into the mountains proper, it has many different types of forms of landslides, and we certainly appreciated that we had a very good chance of getting one, and we haven't done anything with it, we just wanted to see what would happen.

The interesting point here is that to my knowledge the pipe has really not moved appreciably up to 1973. I believe that it has moved slightly towards the end of 1974, but I am not positive about that. Certainly there was no movement to the pipe for three years, and as I say, any of the measures that we propose to use are, in our opinion, fully capable of preventing anything of this sort from occurring.

Thank you.

THE COMMISSIONER: Thank you, Dr. McRoberts.

MR. SCOTT: Before you turn

the photograph off, Dr. McRoberts, could I have the first one?

A Yes.

Q From what elevation would that be taken?

A I don't know, Mr. Scott. I didn't take the picture in the first place, but this scale here, the clearing would be how far, 200 feet.

WITNESS WILLIAMS: It would be about 100 feet wide.

WITNESS McROBERTS: It would be about 100 feet wide. This section from here to here we put in an 80-foot section of pipe.

Q Is that the lower section?

A This is from about here to here, is about 80 feet, and there's another 80 feet here of ditch that was dug but no pipe was put in.

Q I asked because Mr. Gibbs was in some alarm when he saw the short man, he thought you were putting in a 60-inch pipe.

Is that an example from the air, of subsidance? What's that ditch that runs along?

A This ditch here was the section of the inactive site that was dug and then backfilled.

Q So that the site is filled?

A I beg pardon?

Q The pipe is in the ground--

A There is no pipe in the ground from here to here.

Q I see.

A And in fact because there is no pipe, we are missing about 10 cubic feet of volume per foot run of pipe, so that if there had been that pipe in the ground, then there would in fact be a mound left over here.

Q I see.

A The backfill, because there was no longer any peak to protect up in this section, and because we came in here and we dug a ditch, we put everything back that would be got, more or less, I imagine there might have been a small amount of material just left here --

Q What I'm getting at, Dr. McRoberts, is, is that an empty trench or is it a filled trench we can see?

A The trench here was filled with backfill.

Q So the photograph shows it as filled?

A There is a depression across the trench of, I would say, up to about a foot.

Q Yes, so there is a depth in the trench of a foot after it's been filled.

A Yes.

Q Why is that?

A Because there was no

pipe put in the ditch.

Q I see. Well now, dealing with the conditions, sir, I take it, Mr. Williams, it's obvious to say, is it, that you didn't intend this modified disaster to occur for the purpose of having a slide for us.

WITNESS WILLIAMS: Well, Mr. Scott, we weren't exactly babes in the woods, but we were like Alice, we were wondering about a few things so we installed this test-site.

Q Yes, you tried to do the best you could on that site. It wasn't a planned failure, was it?

A It wasn't a planned failure, no sir. But we didn't do the best we were capable of, no.

Q You know that now, don't you?

A And certainly I knew it then.

Q Why would you conduct ah experiment based on less than your best knowledge of how to do things? What kind of experiment is that?

A That's part of the learning process, I would say. We wanted to see what would happen.

Q Well, you wanted to show what would happen if you used inadequate techniques, is that what you're telling us?

I put it to you, and I hope I am being fair, Mr. Williams, that when you laid this pipe you attempted to do, within reason, the best job that you knew how to do at that time. You've learned a lot since, but it was the best job you knew how to do at that time?

A No, I really wouldn't say that. The technique of installing sack breakers on slopes of this nature is fairly standard pipeline construction practice. We chose not to do that.

Q But your construction of the pipe, your burial of the pipe, your filling in, was the -- I put it to you, the way you would have done in the state of knowledge at that time?

A No, sir.

Q No.

WITNESS MCROBERTS:

A It was also well appreciated in 1970 that if you used bulldozers to clear terrain, that you could expect damage to occur, and it was chosen to clear with bulldozer and not by hand.

WITNESS WILLIAMS:

A It's a point of illustration.

Q Bulldozers are not going to be used on this project?

A I beg your pardon?

Q Bulldozers are not going to be used on this project?

A As Dr. McRoberts said, not for clearing on a slope of this magnitude.

Q I see.

A Because that would be hand cleared.

Q Well Dr. McRoberts, let me ask you this: Apart -- you listed the factors that in your judgment contributed to this failure. Leaving aside the construction techniques, the other factors you listed were all conditions such as the ice rich soil, the gradient , the rain and so on. Those are all factors that occur in nature at one place or another?

WITNESS MCROBERTS:

A That's correct.

Q Yes. They're all factors, therefore, that we may anticipate will occur from place to place in varying combinations throughout this pipeline?

A That is correct.

Q And I take it that just listing those factors, can't we agree that that illustrates as graphically as can be done, the necessity for detailed knowledge of the conditions of the site of each specific site?

A No, I wouldn't suggest that it indicates that you need detailed knowledge of

each specific site. You would find, by and large, that a site that occurred in this type of terrain and that kind of flow, would be reasons of their geologic history would be very similar, and you would expect the conditions to repeat over many hundreds of miles of slopes throughout the Mackenzie River Valley.

Q I see.

A And you would find active features like this over many hundreds of miles of slope.

Q And would you agree with me that it illustrates clearly the importance of identifying and analyzing in depth, the problem areas as they are found throughout the pipeline?

A Yes, I couldn't agree with you more and that's what I'm doing.

Q Yes. And that really will involve hundreds of locations?

A I wouldn't say it would involve hundreds of locations, no.

Q How many locations do you think it will involve?

A I would suggest that for this type of slope failure --

Q I'm not talking just about that type of slope failure, I'm talking about other failures that may be unconnected with those.

A I understood you to be talking about the combination of circumstances that I was talking about, mainly thin peat cover, soil type, ice content, and given that combination of

circumstances, I would say right now we have a preliminary idea of how many slopes of this type, and this combination of circumstances that we will be dealing with. I have in one of the slope reports that I prepared for Arctic Gas, a catalogue of slopes that, albeit be a preliminary catalogue, that will be updated during the final design stage, we have, right now, a pretty darn good idea of how many sites we have, and where their locations are.

Q Would you want to drill an area like that at all?

A Certainly, I would drill a representative number of these types of slopes.

Q At what interval ?

A It would depend how many -- in what interval you mean, on a mileage basis along the pipeline?

Q On any basis you're prepared to tell me.

A I would say that for a critical combination which we are talking about, I would subdivide it into a climatological region because obviously the depth and the rate of thaw is of some consequence, given a general climatological region, I would then consider the terrain type that I was dealing with, and then on that basis decide how many slopes I had to look at until I had a good feel for what's there.

Q I take it that there would be about 700 slopes on the route that would

match a proportion of the configuration that is shown here?

A No.

Q How many would there be?

A I would -- this slope is overall about -- I would say from the top to the bottom of the slope completely -- you appreciate we didn't clear all the way down as I understand it, I would say that the slope is on average, greater than about 12 degrees in inclination and about 100 feet high.

I would say -- I could refer to a -- that's the approximate --

Q How many slopes of approximately of 12 degrees would there be?

A Could you just give me a minute?

Q Okay.

A Well what specific piece of information would you like?

Q Well first of all, I take that there are almost 700 slopes that have a degree of more than 3 degrees?

A That's correct.

Q Yes. Well, how many would there be, let us say, more than 8 degrees?

A More than 9 degrees, I don't have a calculator, and I'm not a very good adder, but say 150. More than 9 degrees and in

height from -- if one wanted to include slopes that were greater than 100 feet high as this one is, and greater than 9 degrees, then we're talking potentially of worrisome conditions in about 30 slopes.

Q How many slopes are of a degree,let us say, more than 10 or 12, whatever figure is convenient.

A More than 12, I would say there's about 100 --

Q Yes.

A -- of which I guess, of which about 80 are less than 100 feet high.

Q Yes. Well now, I take it that the combination of physical circumstances that occurred here will not necessarily occur in all of those, or even in many of them?

A Most certainly, the catalogue -- the table I'm looking at, and perhaps I should tell you what the table is, it's Table 1.2.1 in the report, interim report draught "Slope Stability and Permafrost Terrain" of December, 1974. I have no page number for it. It follows page 4.

And this table was put together using the most conservative assessments of terrain conditions along the right-of-way.

Q Well that was because you are not taking any risks at all, I understand that.

A No, I wanted to put together a composite picture of the number of slopes I had, considering the worst conditions, I wasn't

taking any risks when I was doing that.

Q Well I take it that this kind of combination of physical circumstances can occur in varying proportions and combinations on other slopes that are less than 10 or 12 degrees?

A Yes, that's correct.

Q Yes. So that subsidance of this type is a risk in a wide variety of slopes, depending on what you know about the underlying soil, what you can predict about the rainfall and a variety of other physical factors?

A Yes, and no. As I pointed out here, counsellor, the slope angle here was 8 degrees and it does -- it's between 7 to 9 degrees in the section. The terrain conditions that we encountered in here are, in my opinion, given the thin moss cover and the very high ice rich -- the very high ice contents of the soil and the soil type itself, are more or less the worst condition which is why Mr. Williams put the facility in here in the first place, and in fact, nothing, as you quite clearly see happened.

Under those circumstances, I would say the slopes less than 9 degrees have in fact performed adequately well, and it is only the slopes over say 9 degrees that worry me and we have addressed ourselves to how many they are. And of those, many would not encounter the -- in the steeper -- you will understand in the type of matrix of classification I have developed, I have had to -- excuse me,

categorize or catalogue the slope based on the average sloping inclination and the total height, in order to expediently package the information. And many conditions on the higher slope, we also -- excuse me, we also classify them as being potentially unstable, based on the terrain feature that occurs on top of the bank.

Now, under many circumstances in fact, the terrain feature, let us say it is GLB, is the surface veneer, but underlying that surface veneer and going down, you may encounter till, which is is much more stable and in fact bedrock, but under many of the remainder of those slopes, you find characteristically because of the natural processes that form the slopes, that the more susceptible material would have failed long in the past, and they are more or less at stable angles and that then in turn overlie other material that is inherently more stable.

Q Now, could I just have the third slide, please?

No, I'm sorry, it's the other one.

Now that's after the repair work is underway, is it?

A There's been no repair work done here at all.

Q I see, that is the slide, that's how the slide looks after it is cleared.

A This picture was taken, as I thought I had made clear, in the fall of 1974.

Q To what depth was the pipe buried?

WITNESS WILLIAMS:

A I think it had about three to three and a half feet of cover, Mr. Scott.

Q Thank you.

WITNESS MCROBERTS:

A I think perhaps you can see -- you probably could get a good indication here, Mr. Scott.

Q I see.

A You can see the total change between here and here, and that may have something to do with it.

Q Yes. Now, what volume of earth, approximately, would have been moved by that slide?

A Over a period of four years now that we're talking about, let's say about 20 yards wide by one yard deep, that's 20 yards times 20 yards down the slope, that's 400 square yards --

Q Yes.

A -- in four years, a hundred yards per year.

Q That would be regarded as a relatively modest slide, wouldn't it?

A I would say that it wasn't a modest slide, no. It is very similar to the type of landslide that -- well, it is in fact a type of landslide the way it's now developed that I would call a skin flow, and you can find in fact, I would say, quite modest in regards to the extent that it still hasn't occurred over the entire width of the right-of-way. You find this type of landslide occurring in river banks similar to what you find here, over miles of the same river bank one after the other.

MR. SCOTT: I take it, Mr. Genest, that the construction panel will be dealing with repair questions? Is that correct?

MR. GENEST: Either the constu-ruction or operation and maintenance.

MR. SCOTT: Perhaps Mr. Williams just knows, while I think of it, what sort of equipment would be brought in to repair a slide of that dimension?

WITNESS WILLIAMS: If this occurred all at once, as it didn't, there were pre-liminary indications that this was happening and --

Q Well, assume it did occur all at once.

A Assuming it occurred all at once, if the security of the pipeline was not in danger, then I would think the operation and maintenance

people would wait until wintertime and they would come in with fairly heavy equipment, haul in additional material and repair the drainage protection dykes. You could have equipment up to D-7 size equipment, Mr. Scott.

Q If the integrity of the pipe was at issue, at risk, and it had to be done in the spring or summer, what would be done?

A Then the emphasis would be on soft track equipment, or if the terrain allowed, emphasis would be put on an air cushioned vehicle to bring the equipment and the repair materials in. Helicopters would also be relied on to the greatest extent possible.

WITNESS McROBERTS: Possibly I could also point out that given our understanding of the mechanism of failure in this type -- that is involved in this type of failure, complimented in fact by our actual experience here, the integrity of the pipe would not be threatened under any conceivable circumstances that I can think of the first year.

Q Is that -- without getting into too much detail -- is that the, is that physically the dimension of the failure that occurred on the Pointed Mountain line, or is it greater or smaller in terms of volumes of earth?

A I know nothing about the Pointed Mounted line.

Q Well, in terms of volume

of earth, Dr. Hardy, is that same size, smaller or greater?

WITNESS HARDY: In the Pointed Mountain situation, there were -- there was one location very similar to this, we haven't even discussed. But of the ones that we have discussed, at crossings, the dimensions far exceeded the dimensions here.

Q Yes, would they be eight or ten times the dimensions shown there?

A Well, probably not more than ten times.

Q Yes. All right, thank you. Now, Mr. Williams, I have no further questions in connection with the slides.

Mr Williams, at Sans Sault or any other test site, have experiments been conducted with the recommended stabilization measures for shallow slope instability?

WITNESS WILLIAMS: We did undertake two restoration operations at Sans Sault, I think it was inactive section 2 on the bank of the Mackenzie, and six, which was across -- the one across the Narrow Creek, we did some restoration. Now whether that's the prescribed method --

Q I raise the question because in the application there are certain recommended stabilization measures that the applicant indicates he will utilize in the event of shallow slope instabilities

and I just wondered if you knew offhand whether any of those techniques had been used at this or any other test site in order to test them out.

A I'd have to review what the application says with respect to restoration, Mr. Scott. I can tell you what did go on at Sans Sault with respect to restoration.

Q Well, let me ask you this. Has any report or study or is there any catalogue of the way the stabilization techniques that you used at Sans Sault worked and performed in the ground?

A Not -- I think the method used may have been dealt briefly in this report, and the effectiveness of the repair is, I don't think is in an engineering report, it may be in a report prepared by the botonist, I'm not sure, Mr. Scott.

Q I'm simply concerned because inadvertently, I've no doubt, you had an opportunity to utilize the recommended courses at this test-site and I wondered if any studies have been done of which you're aware on how they worked. Now if you don't have that information, perhaps you can find it for us on a later occasion if it exists.

WITNESS HARDY: You appreciate, though, Mr. Scott, that this sort of failure in these pictures is not new to the pipeline practice in the northwestern part of this continent, and so it would be a mistake to assume that the remedial measures that are in that report are dealing with completely

new situations, as far as the people who offered that report are concerned.

Q Oh no, but I would, Mr. Williams, ask if there is any report that you could ask your counsel to produce it to us, it seems to us consistent with seizing every opportunity to experiment this would have been a suitable occasion to do so.

WITNESS WILLIAMS: I'd like -- Dr. McRoberts reminds me that probably in one of the later Sans Sault reports that are on the list, there are some pictures of the re-vegetation at the inactive section No. 6 on the bank of the Mackenzie and probably at the Small Creek crossing, I would have to review that to answer properly.

MR. GENEST: Mr. Scott, could I interrupt? I just want to be clear on the kind of report you're trying to ascertain exists.

MR. SCOTT: Well, I want to know first of all if any of the recommended stabilization techniques were tested at this test-site or indeed at any other.

Our research report doesn't indicate anything about that.

If they were tested there with this or other opportunities, it would be helpful to see them.

MR. GENEST: This would be a test of recommended stabilization techniques which does not exist as a matter of conventional pipeline practice.

MR. SCOTT: No, I am simply saying there may be conventional techniques. I am simply observing that in a sense a golden opportunity was made available to the applicant to test its techniques on the ground, and I wondered if that was done and what the results of it were.

Q Well now, I'd like to turn to one other matter. Dr. Slusarchuk, are you familiar with the work of Linell, reported at the Second Permafrost Conference based on Alaskan experience which indicates that the removal of trees is a consequential factor of importance in degrading permafrost?

WITNESS SLUSARCHUK: I think I perused that report, sir. I have no specific details of it.

Q Well, just so we'll have it as a matter of record, the report is by Kenneth A. Linell of the U.S. Army Cold Regions Research & Engineering Laboratory, entitled:

"Long Term Effects of Vegetative Cover of Permafrost stability in an area of discontinuous permafrost."

That was a paper tendered, as I understand it, at the Second Permafrost Conference in the Soviet Union.

A Yes sir, I'm generally familiar with that piece of work.

Q I will try and tender a copy of that report because it contains a graph.

Sorry, Mr. Commissioner, I don't have copies of the graph but I wonder if Dr. Slusarchuk could look at it and see if he agrees with the conclusions that are illustrated in the graph, and then we can --

A   Yes, I've seen this graph previous, and I think this graph is a statement of fact, there's nothing to disagree with.

Q   You don't quarrel with it?

A   No, I don't quarrel with that.

Q   What does that show about the effect on permafrost of the removal of a tree cover over a period of years?

A   In this case, it indicates that permafrost will degrade with time.

Q   Well, can you give us -- because I don't read graphs very well, especially when they're not here -- the figures in that example?

A   In this graph there are two areas, sir. There is under the trees and the moss, and in one case they just removed the moss and in the other case they removed the trees, and in another case they removed the trees and the moss. Do you want me to give you the figures here or here?

Q   Perhaps you can tell us in depth of degradation the effect of removing the trees.

A   According to this graph

after 26 years, for example, the permafrost had degraded from about three feet to about 13 or 14 feet, after 26 years.

Q Where does 26 years appear? Is it on one of the -- I see. What is the degradation from the removal of trees after, let us say, five years?

A After five years, the permafrost table has moved down from a depth of about three feet to about five to six feet. This is actually given in meters, I can give them to you in meters.

Q All right, well I am handling Celsius at the moment, I'm not on to meters yet.

A Okay.

MR. GENEST: Would the figures 3 to 13 metres?

A No, sir, I am translating in feet.

MR. SCOTT:

Q Well now, would it be a fair conclusion from that example, that the most pronounced degradation of permafrost results from the removal of trees?

A The most or a most?

Q Compare the effect, if you can, from the graph of the removal of trees on permafrost as opposed to the removal of what I take it to be moss and peat --

A Yes, removing the trees has a significant effect on the degradation of permafrost.

Q Well, would you agree with me that obviously the removal of peat and moss

continues the process, but that the most marked effect results from the removal of trees?

A That doesn't -- that's not what this graph shows,sir. Here's -- you can see it here, this is where the trees are removed, these this is where the trees and the moss is removed. Now --

Q Take five years.

A Well in five years under one section it's degraded about three feet where the trees are removed, and then the other degraded about six feet.

Q All right. I will try and tender that as an Exhibit, Mr. Commissioner.

(REPORT ENTITLED "LONG TERM EFFECTS OF VEGETATIVE COVER ON PERMAFROST STABILITY IN AN AREA OF DISCONTINUOUS PERMAFROST" MARKED EX. 96)

Q Well would you, did you hear Professor MacKay give his evidence in the overview?

MR. GENEST: Excuse me, sir, can we give them an exhibit number now, sir?

THE COMMISSIONER: Yes, 96.

MR. SCOTT:

Q Did you hear Professor MacKay's evidence in the overview?

A No sir, I did not.

Q No. Well would you agree with the proposition that generally speaking, the removal of trees has a very marked effect in terms

of degradation over a five year period?

A It does sir, it doesn't necessarily mean it's going to degrade, but it certainly can and it does have a marked effect where it will degrade, that's for sure.

Q Yes. Well I -- you perhaps haven't read the paper and I won't ask you to do so.

MR. GENEST: I'm sorry, I may have created some confusion. The exhibit that I understand that Mr. Scott will be tendering is the graph, and not the whole report.

MR. SCOTT: Well, I'm going to table the whole report and it's subject to proof in the usual way.

MR. GENEST: Well in effect if the rest of the report is not proved, it's not evidence.

MR. SCOTT: Well the graph will be evidence.

MR. GENEST: The graph is evidence.

MR. SCOTT:

Q Well Dr. Slusarchuk, I want to ask you whether you have formed any judgment as to whether the simple revegetation of the right-of-way will prevent the degradation that occurs as a result of the loss of tree cover?

WITNESS SLUSARCHUK:

A Yes, I think I've formed

an opinion.

Q What is your opinion?

A Well the revegetation of, you say of the right-of-way, as I understand it, the revegetation is only going to take place where it's been disturbed, not across the whole right-of-way, so we're just talking about the mound over the top of the pipe. Is this what you have in mind?

Q Well let me put this situation to you. Let us assume a situation in which over five -- in which both tree cover and vegetation have been removed on the right-of-way?

A Yes, sir.

Q And let us assume for the purposes of the example, a case that is given in the graph,that is at five years, that the tree level, the tree removal has reduced the permafrost to six feet --

A Yes, sir.

Q -- and the peat and moss removal has removed an additional three feet. So the permafrost has degraded then from three feet to nine feet?

A In --

Q In this example.

A In your example, yes, sir.

Q Now what -- have you any -- what is your opinion as to the effect on the permafrost of revegetation by sowing grass seed in the -- well at say, in the second year after removal?

A Well, are you asking me to consider that we don't have a pipe underneath it and that within about two or three years the pipe is going to come on and be cold? You're just talking about some situation where we stripped off --

Q For the moment, yes.

A Well, you are going to get something like you got in the graph there.

Q Yes. Well I'm asking you what the revegetation by the sowing of random grass seeds, or even the best grass seeds, is going to do to restore the permafrost?

A I think that if you just put grass seed back on there you would end up degrading the permafrost for the first few years similar to what you've seen on that graph.

Q Yes. Well now, --

THE COMMISSONER: Mr. Scott, just to clarify, your assumption is that the whole width of the right-of-way is stripped of vegetation?

MR. SCOTT: Well I'm not saying that, I'm saying --

THE COMMISSIONER: Well that's how I understood your question, your assumptions.

MR. SCOTT: I'm taking a strip, I don't care how wide it is, I don't know how wide you are going to make it, and I take it that that's your answer with respect to that situation?

WITNESS SLUSARCHUK:

A Well I thought we weren't

even talking about a right-of-way, we were just talking about some area that is stripped of grass and trees, grass and moss and reseeded --

Q Yes.

A -- and what was going to happen, and in that case I think what's going to happen is what you see on the graph.

Q Well, all right.

A In most cases.

Q Now, to what extent will the situation be different if a pipe is buried and no chilled air put through it?

A Well you have to keep in mind the two dimensionality of our situation, with regard to the thickness of permafrost and how wide a strip we're -- we are in fact removing, and if in that case -- if for example, the disturbed area was only say the width of the pipe, just to get the pipe in, because you're talking about a hypothetical case here, and then put your pipe in, you wouldn't get the type of permafrost degradation that you're talking about there.

You would get a dip, but you wouldn't go like that, because of that permafrost on either side of it would affect it.

Q Yes. I take it what you're saying is that a dimension that must be considered is the width of the strip --

A Yes, sir.

Q -- that you expose?

A Yes, sir.

Q Well now, what is the consequence in your judgment if you have formed one, about chilling the pipe two years after the stripping, or three years after the stripping and the laying of the pipe?

A I think it will stop the permafrost degradation completely, in fact it will -- well it will stop it and return it at least to its former level.

Q Now let me read you one statement from Linell's paper --

THE COMMISSIONER: Excuse me, what will restore it to its former level?

A The cold pipe, sir.

Q The passage of chilled air or gas through the pipe?

A Yes sir, and we are talking about the -- as I understand it, we are talking about the mound above the pipe that's been -- trees have been taken away and it's now in a bare state, been reseeded and two years later we turn the pipe on, it's now cold, and the question is whether or not -- or what's going to happen to that permafrost, and I'm saying the cold pipe is going to stop the permafrost from degrading.

MR. SCOTT:

Q Well now, Linell is not talking about a pipeline situation, but I want to put this statement of his conclusions from his report to

you and see if you agreewith it.

"It is concluded that in an environment like that at Fairbanks, the maintenance or re-establishment of a random mix type low vegetative cover cannot be counted on to stop or prevent permafrost degradation in an area subject to surface disturbance".

A I agree with that, sir.

THE COMMISSIONER: The revegetation doesn't assist in the storing of permafrost, it's the passage of the chilled air or gas to the pipe that is effective, is that the point?

A That's the point here, yes.

Q That is your point?

A Yes, sir. It certainly assists, but there is no -- the revegetation would assist to slow down the degradation. I don't want to get the point that I'm not saying that, but what's really going to stop it is the cold pipe.

Q Yes.

WITNESS MORGENSTERN:

A I might add a coment, Mr. Scott, to put this in context, the Fairbanks site that I know fairly well is very warm permafrost and we should bear that in mind. It's not characteristic of the ground temperature along this whole pipeline.

MR. SCOTT:

Q Well I think we heard yesterday that the relatively warm permafrost, south of Willowlake, 31.9, that would be typical,wouldn't it?

A Yes.

Q It's not only comparable, but in terms of warmth, warmer than Fairbanks?

A The same sort of region.

WITNESS SLUSARCHUK:

A All of the permafrost south of Willowlake River is not at 31.9 degrees, sir.

Q No, but it's warmer than the permafrost further north?

A Certainly.

Q Well now, let's take another example. That deals with the pipe. I understand that the applicant is going to build a winter road south of Norman Wells, is that correct, is that your understanding?

A I'm not sure, sir.

Q Well isn't that so, Mr. Williams?

WITNESS WILLIAMS:

A I feel reasonably sure that there are several winter roads proposed south of Norman Wells.

Q Well you proposed several winter roads, isn't that correct?

A Yes, I'm sure that's shown

in our construction plans.

Q And in all probability, without tying you down, there's going to be a winter road that will probably come down close to the Alberta border?

A Yes, we show several winter roads in that area.

Q And you're going to strip the tree cover in order to build those roads?

A Yes, carefully.

Q Well now, Dr. Slusarchuk, what do you say about the effect on the permafrost in the event that the tree cover and perhaps the low lying vegetation is stripped in order to build a winter road?

WITNESS SLUSARCHUK:

A There's a good chance it's going to degrade, sir.

Q To the degrees that were shown in Linell's article?

A I don't -- I think in general terms it will be, but as I understand the procedure that is taking place at that test-site, the data that's actually being reported, year after year they go in and make sure that the moss and the grass is removed and that the small brush is cut down. It's a different situation with ours, as time goes along, of course, we wouldn't go in there year after year and do that.

Q Well now, let's take one other example. I understand, Mr. Williams, that a winter road is going to be built down the easement for the purpose, for at least one or two years, of constructing the pipeline.

WITNESS WILLIAMS: Yes sir, that would be the snow road and winter road would be incorporated in the pipeline right-of-way to the extent possible.

Q Yes, and that will be a road of what width?

A Oh, in the neighborhood of 30 feet.

Q Yes. Well now, Dr. Slusarchuk, in view of Linell's experience, what is your judgment about the effect on the permafrost of the construction and the usage of that road along the easement?

WITNESS SLUSARCHUK: It is quite possible that it will degrade there too, in some cases.

Q Yes, and do you agree that it will degrade, or it may degrade to the extent that Linell has indicated?

A With the -- in general terms, yes, but keeping in mind that they've gone back there year after year to clear out the new vegetation that comes in, as this new vegetation comes in it tends to reduce the rate of degradation. So from that point of view it would be a little bit less for the same situation there.

Q But that's not tree vegetation, is it? That's grasses and low shrubs.

A Well, there's two areas there that they're talking about, sir. There's the trees, and they removed the trees, and then they removed the moss as well as the trees.

Q Yes, but I take it that nothing -- I'm sorry.

A Well, in what I've said there, that under the areas where they said they removed the trees, I understand that year after year they come and clean out all the small brush to make sure that there are no trees starting to grow up in there, and where they've removed the moss, year after year they go in there and remove that to make sure that nothing is coming up to change the initial

conditions that they set out to look at. That would really be a worst case situation, if you allowed the vegetation to start to re-establish itself, the rates of degradation would be naturally somewhat less. It wouldn't necessarily be impeded, but it would be a little bit less.

Q Well now, you've done some experiments at the test facility with respect to re-vegetation, I understand.

WITNESS WILLIAMS: Certainly re-vegetation tests were conducted at all sites.

Q Yes, and Dr. Slusarchuk, are those tests consistent with the opinion and judgment that you've given today?

WITNESS SLUSARCHUK: I think they are, sir.

Q And I take it then that what we may anticipate is that where there are roadways which have necessitated a tree cover removal, that there will be fairly substantial degradation of permafrost.

A In some cases, sir, yes.

Q What is the practical implication of that degradation?

A You're going to get settlement, thaw settlement in ice-rich permafrost, that's one implication.

Q Is there any other implication in terms of water?

A Perhaps you could ask me the question you're trying to lead me to, sir.

Q No, I'm not trying to lead you to any. I'm just trying to find out. This is one case I'm not leading you to an answer. Are there any -- obviously it's going to subside. Are there any other consequences?

A Well, are you talking about drainage and erosion, sir? Are you talking about the water that's thawing that has to come up to the surface?

Q Yes, what's going to happen to that water, for example?

A It's going to tend to migrate towards the surface as the soil settles.

Q And then what's going to happen to it when it comes to the surface?

A Well, I guess a great number of things could happen to it. It could evaporate, it could run downhill if it was on a slope, it could just pond.

Q And then in winter I take it it will freeze.

A Well, I would assume so, with that surface.

WITNESS MORGENSTERN: May I comment, Mr. Scott, to stress the qualification that Dr. Slusarchuk noted that we'll get settlement when we have degradation in ice-rich permafrost? We have

examples from the Mackenzie Valley of more substantial degradation than Linell finds and there is no discernible settlement at these locations, and the reason why the degradation of warming is so rapid, so extensive, the fact is because the ground is likely to be very ice-poor and the good state of the surface of the ground also reflects the fact that the ground was ice-poor. So we should bear that distinction in mind.

Q There is going to be lots of ice-rich soil between Willow Lake and the Alberta border, isn't there?

A There will be some, but the more ice-rich the material, the less the extent of degradation in a given period of time.

Q Because if in that area there wasn't much ice-rich soil, that would be a factor that would favor stopping the chill of the pipeline earlier, isn't it?

A It would be a consideration.

Q Yes. So we may anticipate because of your conclusion that the pipeline is going to be chilled to the Alberta border, that you're doing that in part because there will be substantial deposits of ice-rich soil.

A Yes.

Q so it's either one or the other. You could stop the chilling or you're going to have this degradation.

A My point was to draw attention that degradation to us means a warming of the ground. It's only when one degrades ice-rich permafrost that we get settlement of the ground.

Q Well now, Dr. Slusarchuk, if there is an accumulation of water, is that going to have any effect on degradation?

WITNESS SLUSARCHUK: You're talking about this water now coming up, percolating up to the surface?

Q Yes.

A It would tend to reduce the rate of thawing.

Q Well, isn't it one of your theories --

A The movement, the movement of the water up towards the surface would tend to reduce the rate of thawing.

Q But if there are pools of water that collect on the surface, does that have any effect on the degradation of permafrost?

A Yes, it tends to keep the ground a little bit warmer under those pools, so it increases the rate --

Q It increases the rate and extent of degradation.

A How big of a pool are you talking about? I mean are we covering -- if we're talking about the kind of pools, for example, that

we'd find along the rights of ways, along the test-sites, for example, it will increase marginally in the first year or two, and after that it wouldn't increase it too much because there are two dimensional effects start to come in.

Q Indeed the pool at one of the test-sites, I forget whether it's Calgary or Sans Sault, has indeed increased the degradation of the permafrost under the pool, hasn't it?

A I don't have knowledge of that, sir.

Q Isn't that so, Mr. Williams?

WITNESS WILLIAMS: I'm not sure.

Q As a matter of principle, Dr. Slusarchuk, there's no doubt that it would, is there?

WITNESS SLUSARCHUK: No, I don't think so, for the first few years, you know.

Q Well, the rate of degradation declines, as you pointed out earlier.

A Just in general it does. No water there at all, but then what I'm also saying is that if you have a small pool, it has more effect in the first few feet because it's acting more like a one-dimensional heat supply, you might think of it as a lake with regard to the first foot or so; but as the thaw starts to degrade farther and farther down, you

start to get the influence of the cold permafrost around it, and it tends to reduce the rate that you have under there.

Q So would you agree with me that in these situations where they occur, drainage becomes a truly important question?

A To drain the ponds?

Q To see that there is no, as the permafrost degrades, that the water is rapidly removed so that it doesn't pond.

A I don't agree with you that small ponds on the right-of-way are -- have to be drained right away, or have to be gotten rid of, no sir.

Q Well, let me put it this way. The development of these small ponds is going to add to the existing drainage problems, of which we've heard. There is going to be an accumulation of water that will add to the normal drainage.

A If you're -- I'm not sure if you're implying, sir, that the amount of water that's released and fed to the surface is a significant portion compared to the normal drainage, because if that's what you're implying, the answer is quite clearly, "No." It's an insignificant amount that's going to be thawed and released up to what naturally has to be drained across the surface or through the active layer in the earth.

Q Well, is there any risk

that the surface water will collect in the degraded holes?

A Oh yes.

Q All right, then doesn't that add to your drainage problems?

A Well, you have to talk to somebody else about drainage.

Q No, but just so I'll have it clear, if we're going to have subsidance, not in all places, as Dr. Morgenstern has pointed out, but if we're going to have subsidance from place to place where there were ice-rich soils, adjacent to the roadways, if not the pipeline right-of-way, now what was I going to ask?

(LAUGHTER)

A We're even now, sir.

Q I don't think so. If those ponds are going to develop -- and when I say "ponds" I mean areas of subsidance in which water collects, isn't that going to create a run-off drainage problem because the water that comes down the slope or across the land will gravitate towards those ponds?

A Well, it's not --

Q In subsidance areas.

A Yes, it will, and it will fill, if the water table is high at that time it will in fact show as a pond and you'll see it there, but the point that I'm trying to make is that what you've just identified is not equated to a major problem, in all instances.

Q Well, because it doesn't affect the integrity of the line?

A These -- it depends on the size of the pond. There is no way you can stop these small ponds from developing, we know that, and there are just hundreds of them up there and if it does degrade, it's going to degrade unevenly from place to place, as you're implying, and you're going to have small ponds and it's not necessarily going to degrade the permafrost faster in that area. I guess, if you want to have an answer what that means with regard to drainage and erosion, I'm going to have to actually turn it over to somebody that talks about drainage.

Q Well we will be dealing with drainage and erosion later. I would feel better if I thought you were going to stock the ponds, but --

A I don't think the fish biologists would go with that sir, because I am sure they die pretty fast.

Q Mr. Williams, are you continuing your observations with respect to revegetation at any of the test sites?

WITNESS WILLIAMS:

A Yes sir, every summer the -- our staff botanists go to Sans Sault at least, I'm not sure what they do at the other sites, but I know they have been going there every year.

Q And I take it that reports are made at intervals so we may anticipate a report on the progress of that in the early autumn?

Assuming were here?

A I would expect so, sir. I think they are included in the biological report series up to that point in time. They're probably preparing additional reports on their observations last summer.

Q Well now, you have set out I think in the application certain observations about the environmental effects of winter roads, as you understand them. Are -- have you any conclusions about the effects of winter roads over the long term? Or any studies or any reports that deal with that subject?

A Probably a report done in oh 1970 or '71 by R.M. Hardy and Associates that -- where they observed a great number of disturbances in the north and they took survey measurements and so forth. That's one report.

We of course,we --

Q I'm trying to zero in, we've seen some of your reports. I'm trying to zero in on the test sites. Now at the test sites you had winter roads. Have you done any work or made any reports or collected any data of the effects of those winter roads at the test sites that we can have?

A I feel sure that the botanists included in some of their reports some observations of that attempted construction of a winter road at Sans Sault that I illustrated on the slides. I know for sure that they have done a --

they have recently published a report on the surface vegetation situation at Inuvik following, the summer following that snow road test at Inuvik.

That report, I think, came out in December of '74.

Q Well at the test sites, have they done any work on winter roads and degradation?

WITNESS MCROBERTS:

A There is some studies reported in a report entitled, I'm paraphrasing the title, "Geothermal and Meteorological Observations" at the Sans Sault facility, in which the amount of thaw in one or two transects crossed a winter roads is presented.

Q Apart from that, is any currently being done, Dr. Williams, Mr. Williams?

WITNESS WILLIAMS:

A The botanist will be doing a -- or will be continuing their observations at Sans Sault and at Inuvik. I -- and they have studied other disturbances in the north, they are working around -- have done some work around Tuk, I'm pretty sure.

Q I take it then, is it fair to say that whatever else you may be doing at Sans Sault, you're not following through any studies with respect to the effect of winter roads and degradation there, nearby?

A Not from an engineering

aspect, but I think the botanists do this in their vegetation study, and I think they record some of those depths in their studies. I know for sure at Sans Sault on the active sections, that they have reported I think over -- at least the first two years of operation of the test site, the surface -- the level of the permafrost across the right-of-way, and have tied it into their various grasses that they seeded there.

Q So if we are going to get it with respect to Sans Sault, we're going to get it from a botanist, is that the picture?

A Yes, sir.

Q Yes.

Those are all the questions I have on this phase, Mr. Commissioner. I'm moving to a new subject. Is this a convenient time?

THE COMMISSIONER: Yes, this phase of this panel, not --

Well we will adjourn til 2:30 then.

(PROCEEDINGS ADJOURNED TO 2:30 P.M.)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT: Q Dr. Slusarchuk, I want to ask you if I have the correct definition of a number of terms that may be relevant at a later stage of the Inquiry. First of all, do I understand the expression, "geothermal regime" to be the temperature environment?

WITNESS SLUSARCHUK: The temperature environment and the heat fluxes associated with that, the heat transfer that flows around, yes sir.

Q And do I understand the expression, "geothermal analysis" to indicate the way in which the changes in the geothermal regime are predicted?

A That's reasonable, yes sir.

Q And the "geothermal program" to be the technique by which the analysis is carried out or carried forward?

A That's our main method, our computer program, yes sir.

Q Well now, I take it that you have at least two geothermal programs, one identified as Battell-Brooker, and identified as the E.P.R. program.

A Yes sir.

Q And I understand that the function of these programs in layman's terms is to tell us a number of things, or to tell you a number of things, one is the rate and extent of thaw.

A Yes sir.

Q And that obviously relates to your ability to predict degradation.

A Yes sir.

Q The second is to predict the rate and extent of freezing.

A Yes sir.

Q And that relates directly to your ability to predict heave.

A It does that.

Q And that those two functions are essentially the two functions that the geothermal program is designed to achieve.

A Those are the two main functions, yes sir.

Q And the program is designed to predict the temperature or temperature changes at a variety of depths from the soil surface.

A Yes sir.

Q In other words, it's not concerned with what is called ambient temperature, it's concerned with temperature in the soil.

A It's -- if we're talking about predicting, then we're concerned about predicting in the soil, but we do use the ambient temperature as part of the input to the computer program.

Q It's part of the input but it's not part of the outgo, the objective is to predict temperatures in the soil.

A Absolutely.

Q At various depths.

A Yes sir.

Q And the objective of the program is also to predict those temperatures at various depths at various times in the future.

A Yes sir.

Q And would it be correct to say that in respect of degradation and heave, the geothermal program is an essential component of your ability to respond to these problems?

A It's an integral part of that, of our overall design tools, yes sir.

Q Well now, is it perhaps axiomatic that a program, a computer program or a data program is, in terms of results, only as good as the data, the raw data that is inserted into it?

A Yes sir.

Q And I presume that you would agree that the result of the program, that is the predicted temperature in time and in place, will be extremely sensitive to margins of error with respect to certain kinds of data input.

A Not extremely sensitive, sir, no, it's not.

Q Well, let me put it this way. Margins of error for various kinds of data have been established by the program itself.

A I don't follow that, sir.

Q Well, I take it that there is a wide variety of data that the program calls for in order to make the predictions that are sought.

A Yes sir.

Q And for example, I don't mean to be exhaustive, the data involves wind velocities at various places and times.

A That's one of the inputs.

Q Ambient temperatures at various places and times.

A Yes sir.

Q And a variety of other kinds of statistical information?

A Yes, sir.

Q Yes. Well, is it correct that in collecting the data that is inserted into the program, either the applicant or the -- or those who have developed the process, have established margins of error in respect of the data?

A We don't -- we have not established that, sir, no. Not -- like taking your term "wind speed", for example, we don't have a number that says the wind speed is this plus or minus a certain percent.

Q Well let's take two input data as an example. One of the input data is thermal conductivity?

A Yes, sir.

Q Yes. Now, would you define for us what that data is?

A What thermal conductivity is or what we have obtained our data?

Q What thermal conductivity means?

A Thermal conductivity is the ability to transmit heat through a medium --

Q Yes.

A -- such as ground.

Q Well now, I'm reading from -- before you get to that, let's take another factor, the greenhouse factor, and can you describe in, or

can you define in straightfoward terms, what is represented by that factor?

A The Greenhouse factor is defined as the ratio of the long wave radiation received at ground surface over the long wave radiation emitted from the ground surface.

Q Yes. Well, did that -- just so I'll be sure I understand the mechanism involved, I take it that heat emanating from the sun is reflected off the surface of the earth?

A That's short wave radiation sir, not long wave.

Q I see. Well, where does long wave radiation come from?

A Right now, sir, everybody in here and all things are radiating heat,at a certain temperature.

Q All right.

A And at lower temperatures such as we're used to, we emit long wave radiation.

Q All right. Well now, that's the radiation you're concerned with in the Greenhouse factor?

A Yes, sir.

Q Yes. And I take it that the analog to the Greenhouse is a cloud cover?

A Yes. The ground surface is always -- is at a certain temperature, and it is emitting heat via long wave radiation from that surface. That's one of the components of the energy

balance at the ground surface. Some of this heat is reflected back or re-radiated back because there is a -- the clouds themselves are in fact radiating heat, and it's that ratio of what's come back to what's going up that is Greenhouse factor.

Q And that ratio is measured and is one of the inputs into the program?

A Yes, sir.

Q Yes. Well now, I would like to refer you -- I'll just read the passages, to the final report on Arctic Gas Thermal Soil Behaviour Model to Canadian Arctic Gas, dated August 15th, 1974, of Battell and Brooker, and I take it you're familiar with that report?

A Yes sir, I am.

Q Well now, on page 2, Roman II-26, speaking of input data as I understand it, the authors say with respect to thermal conductivity, and I will only be dealing with these two factors, I'm not concerned with the others --

MR. MARSHALL: Excuse me, Mr. Scott, if I may. Are you going to deal with this report in some detail? If so, I would like to get a copy for the witness.

MR. SCOTT: No, I'm going to read two sentences, but I'm happy to show him mine, if that's convenient.

Q Relating to thermal conductivity, the authors say:

"Thermal conductivity however requires an

accuracy of the order of 20 percent".
Now, is that the margin of error that is fixed for the input data which represents thermal conductivity?

A I'm not sure what they're referring to, why it's fixed at 20 percent there, sir.

Q But they are the authors of the program?

A They are the people that wrote the program, they're not the people that are using this on this project. We are.

Q Would you disagree with their statement that termal conductivity, however, requires an accuracy of an order of 20%?

A Yes sir.

Q You would disagree with that?

A Yes sir.

Q What kind of accuracy is in your judgment required?

A Depends on what I'm trying to analyze, sir.

Q Well, let us presume that you're trying to analyze temperatures in the soil.

A For freezing or for thawing?

Q Well, let's take freezing first. What order of accuracy with respect to thermal conductivity is required?

A The data that we are using in our inputs are geared to that, is the data provided by Kirsten and he puts on an accuracy of plus or minus 25% on that data.

Q And you are therefore inserting thermal conductivity data which relates -- which is plus or minus 25%?

A Well, that's what Kirsten put on his results. We are in fact dealing a whole lot closer to the saturated conditions than what Kirsten was, when we put that number on for all the data that

he presented. So I think that in most cases we are probably better than 25%, probably better than 20%, but it's probably not necessary for us to be that accurate. However, I think in most cases we are.

Q All right. Well, let me read the sentence again, because there is a comment at the end of it:

> Thermal conductivity, however, requires an accuracy of the order of 20%, which is difficult to attain."

Do you agree that data of an accuracy of that order would be difficult to attain?

A If they're talking about the complete spectrum of thermal conductivities for unsaturated soils to dry soils, I would agree with that. I don't necessarily agree that that would be the case for the greatest percentage of our situations we are talking about saturated conditions only.

Q Well now, let me come to the green house factor, and can you tell me with respect to the green house factor the order of accuracy that is being utilized in your input? Mr. Genest looks as if he wants to answer this.

MR. GENEST: Mr. Scott, there is an urgent call for Dr. Morgenstern, and Mr. Commissioner, I wonder if he might be excused for two minutes?

THE COMMISSIONER: Certainly.

MR. GENEST: I'm sorry.

A The question was with regard to the accuracy of the green house factor.

MR. SCOTT: The order of accuracy, what you regard as the limits within which you must be in order to obtain an appropriate prediction.

A Well, again it depends on what sort of thing we're after, sir. The accuracy that we require; I'm not aware that we've actually put an order of value on the accuracy with which we have the green house factor, I think we use a number -- if you could just give me one second --

Q Yes.

A I think we use a valve of 0.83 throughout the year on green house factor, and it varies by month, and it does vary a little bit by latitude, but not very much. The numbers that we have, they vary from a low of .81 to .875.

Q Would you be concerned, for example, if you were -- if your input data with respect to green house factor was within 10%?

A If it was within 10%?

Q Yes.

A I think 10% would be fine.

Q What I really meant to say was plus or minus 10%.

A Well, you're still waiting for my answer?

Q Yes.

A I just don't know how to answer that right now, sir. We have not as I recall it, gone through a study that actually shows the values through which that can vary, other than the numbers that I've already given you, and that would not quite be 10%, those numbers that I gave you.

Q Yes, well let me just read you at page II-27, what Battel & Brooker say with respect to the input of the green house factor:

"This has been shown to be an extremely sensitive parameter."

First of all, would you agree with that?

A In some cases it's sensitive; in other cases it's not very sensitive at all, sir.

Q And I take it "sensitive" in that context means likely to affect the result.

A Yes sir.

MR. MARSHALL: Mr. Scott, I think we're going into a lot of detail in this. I would like to get the report so the witness can have in front of him it, and he knows the context within which the terms are being discussed in the report.

MR. SCOTT: Yes, well you can show him this if you want to, but I can read the sentence first.

MR. MARSHALL: Sure.

MR. SCOTT:

"This has been shown to be an extremely

sensitive parameter and accuracy must be to within 6%."

I'm prepared to show you your report.

MR.MARSHALL: We didn't bring them all down here.

A I've got it upstairs in my room, but I didn't realize we were going to be talking about it. At the time that this report was written, it's dated 1974 --

MR. SCOTT: What month is it?

A August, 1974. That is really just an update. The preliminary -- by an "update" I mean an editorial update, not an update of technical knowledge that went into it, and the -- I wish I had my book here that is upstairs, but I think this was done at least a couple of years prior to this because when I joined N.E.S., in '73, April of '73, this was already put out so it must have been sometime prior to that, and I think it was based on information and knowledge -- technical knowledge -- at late 1972, and at that time they had, as their heat flux components tied in with the long wave radiation term or the green house factor term, a term in the energy flux balance at the surface that also contained the evapo transpiration term, and so they were varying the one number and were actually looking for two components of energy at the surface. After I joined we decided upon review that that wasn't adequate and we broke up the two fluxes. We now have one flux for the long-wave

radiation term, where the green house factor comes in, and it only affects that portion of the flux, and the evapotranspiration part is quite separate and I would be very surprised, sir, and -- if they would agree to this statement at this stage, knowing that we've now -- well, they know that we've separated it because we got them to make the change in the program. That's where I think it was found to be so sensitive in this report.

Q I take it that your proposition is that that statement is not the parameter on which you've been relying?

A Well it's one of the many parameters that we input, but it is not a parameter that I would call extremely sensitive.

Q all right. Well, is the Greenhouse data that you were -- let me put it more directly: What is the margin of error that you regard as acceptable with respect to data input covering the Greenhouse factor?

A We haven't gone through a detailed analysis like that, sir, because the combinations and permutations are virtually infinite if we went through that whole procedure.

What we have tried to do is gather together a body of data that we thought was the best that we could do, and we did that and that is reported in our application of geothermal analysis, and we formulated it, or we -- I'm reaching for the -- we made specific decisions on which numbers we would use at what location, because it varies along the route, for example different -- for example the temperature does. We looked at the Greenhouse factor, we saw that it varied with season and it also varied with latitude, but very little, and what we did, we put -- we used average values as input to our computer program.

We adopted our standard values that we thought were the best that we could come up

with by discussing with ourselves, with our consultants and with different people in the government, and also with regard to the published literature that was available, and then we took that and made comparisons with what we were observing in the ground, and what we understood to happen in the ground from our own practical experience, and we find that we get good correlations, so we haven't gone on a -- I think, I don't know how many input parameters we had, some 10 or 15 or maybe more --

Q I'm just talking about two right now.

A Okay, well, on those, other than what I already told you about the thermal conductivity, we haven't gone through and said now this Greenhouse factor has to be at point 83 throughout the year, plus or minus 15 percent, and if it 's not that, our predictions are no good.

Q Well, let me ask you this, Dr. Slusarchuk: What in your judgment would be the effect on the prediction and the ability to predict correctly if the Greenhouse factor was in error, by let us say 10 percent?

A Well, let me give you a specific example, because I keep telling you it depends on what I am analyzing, because we use the geothermal analysis to analyze a great number of things.

Now, for example, if we were worrying about whether or not the active layer would go down beneath the bottom of the pipe during its

inactive period, and we have ran -- and we were predicting in some cases that the thaw depth was four feet or five feet in the bottom of the pipe was eight or nine feet down, and if we varied the Greenhouse factor by a little bit, it probably doesn't change that prediction very much.

Q Well, in that example, is it possible to be more precise? What is the effect of an error in the Greenhouse factor of 10 percent? Not with relation to the pipe, I'm just interested in your predicted value .

A Well, the only way I can be more specific is actually go to an example that we've measured temperatures and predicted temperatures, and show you what they are, such as in our report, for example, on the test facility at Sans Sault, for example.

Q Well, what I really want to get, is have you formed any judgment in any given case, if you want, as to whether an error of 10 percent in the Greenhouse factor is likely to produce an insignificant error in prediction, a moderate error or a subtantial error?

A The judgment that I have formed, sir, is the number that we use is adequate for all the purposes that we require it for, and I haven't gone to that next level to say what level of inaccuracy of input I put there gives me an -- a level of inaccuracy in --

Q All right, well that's

satisfactory to me, at least.

Now, you have referred to some changes or updates of the Battell Brooker report. Are those available?

A You have the update, sir. The one that -- the one that you have, I referred to that as the updated version, but updated mainly from an editorial point of view, not from a technical point of view, that the technical essence in that report --

Q Well I perhaps didn't --

A Was subject to --

Q -- narrow my question sufficiently. You have told us that at, I take it at your request, the Brooker people supervised the division of the Greenhouse factor into two components?

A It was the Battell people, sir.

Q I'm sorry, the Battell people. Have you got the report by which they commented or determined that division?

A They didn't supervise it, sir, they simply carried out an assignment that we gave to them. We determined in consultation with them and with -- amongst ourselves, what form we wanted to have the heat flux component for evapotranspiration, and when that was decided, what they then did was simply went and put that extra -- programmed that extra parameter into the program itself.

Q Well, have you got in writing form, the specifications for that program?

A For the program?

Q For the program -- for the amendment to the program that was achieved when the Greenhouse factor was divided?

A We've got the equations on which they are based in this here book here. It tells you exactly what equation it is, and they've simply just programmed that into the -- they just added that into the program.

In Appendix B of our report on Applications of Geothermal Analysis by Northern Engineering Services, dated June, 1974, we have in there, all the equations that we used for our heat flux components at the ground surface. The short wave radiation, the long wave radiation, the convection and evapotranspiration, and that specific equation to which I am referring to, is in there as Equation D-7.

Q Well, the difficulty that confronts me is that the Battell Brooker report, according to you, and I accept your word, contemplates a Greenhouse factor that you are not using, and makes certain comments about desirable levels of accuracy. You have told me that you are using -- that you have divided the Greenhouse factor into two parts, and as I understand it, you're unable to tell me the measure of accuracy that you judge to be required to obtain a reasonably accurate result?

A I've told you I haven't calculated one, but I have also said, sir, that with the numbers that we have used, I am satisifed that they give us reasonable answers.

Q Well, is there any place where we can find how you have divided -- into what two precise components you have divided the Greenhouse factor, and the level of accuracy that either in your opinion or in the opinion of the developers of the program is required to obtain a reasonably accurate prediction?

A Well, you can find exactly the equations that we used for where the Greenhouse factor is and where the evapotranspiration is in Appendix B. We have them listed as Equations D-4, and Equation D-7.

Q Will I be able to read those and tell the margin of accuracy that the applicant considers adequate to obtain a reasonably accurate prediction?

A No sir, you won't --

Q How do I find that out?

A You won't, sir, because I told you that I haven't calculated that. What you will find in the other section is the numbers that we actually used.

Q Is it difficult to calculate it?

A There is -- if we went into a statistical study on it and looked through all our data and we probably could. You can do all kinds of things with numbers and statistics, particularly when you're talking about weather and long lengths of line and different latitudes and different seasons; but the point is, sir, that there are a lot of components that go into the geothermal analysis.

Q I know, I'm just asking about two at the moment. I think I understand there are many, and if you can't tell me the level of accuracy at the moment that you regard as required, that's the end of the question.

A O.K., that is what I say, sir.

Q All right. What you're telling me is that it can be found by working out the

calculations in Appendix D.

A You can find the exact equations where the green house factors are, and the evapotranspiration which was part of that one input in Appendix D, that is correct.

Q Thank you. Well now, can you tell us with respect to thermal conductivity, the process by which the data is collected?

A For thermal conductivity?

Q For thermal conductivity.

A We searched the literature and extracted from the literature various values for thermal conductivity.

Q Did you make any direct measurements?

A There may have been a very insignificant number of measurements made prior to the time that I joined N.E.S. and some of the component companies, say Arctic Gas or Northwest Projects, I'm not familiar with those. I personally was involved with measuring thermal conductivity when I was with the National Research Council, and I've made a significant number myself.

Q Well, do you evaluate it indirectly then, from the water content? Is that the process?

A We divide thermal -- to get our thermal conductivity based on soil type, in other words we type it as fine-grained soil, coarse-grain soil, or peat or bedrock. And then we further

divide that into what is frozen or unfrozen, and once we determine that we need to know its density and its water content; and knowing all that, we then know --we then have our number for thermal conductivity.

Q I take it with that information you then go to a series of tables.

A Yes sir, we do.

Q Or graphs?

A Yes, and they are in this book in Appendix B, application of geothermal analysis, it's all listed right in there.

Q Well now, would you tell us in the same fashion how you determine the data input for either one or for both of the green house factors, if I may call them that?

A How we obtain --

Q Yes.

A -- the data?

Q Yes.

A We got it from the literature, sir.

Q I see. Is there any actual measurement of that on site at any location?

A I think they tried to make a measurement or two, one or two times at the test-site at Norman Wells, but the equipment wasn't working properly at the time -- this is just my recollection -- and again this is prior to my joining, but we have not been able to, or not had a great body of data to

use on the green house factor that we actually measured ourselves. There may be one or two numbers around for an isolated location, but we do not have a lot of numbers measured.

Q Well, just so that there will be no doubt, the concern is that you may not be able to measure those two components to an acceptable level of accuracy, and that that will affect the prediction. Have you anything to say with respect to that?

A I am satisfied that we can measure them to the -- input them to the accuracy that we need, sir.

Q How do you know that?

A Because we've compared our predictions with measurements that we've had around the operating test-sites.

Q So what you're saying is that the reason you have confidence and the reason you know is that you've taken your predictions and measured them against actual temperatures at various levels of the ground.

A That's the most direct reason. The other way, sir, is that we know from experience what different depths you get of active layer at different times, because we've been up there and we've dug through the active layer, we've measured it, we've seen all kinds of temperature measurements from other people recorded in the literature and are

familiar with it ourselves, and that the general trend of all our results -- of all our analysis is to give very reasonable results.

Q Well, let me ask you this: What in terms of comparing the prediction that you make to an actual measurement, what is to you people the acceptable level for predicting ground temperatures?

A It depends on the particular case that you're interested in, sir.

Q Well, you pick a case in the Mackenzie Valley, because that's where you're going to be predicting ground temperatures, and tell me what your acceptable level is.

A If we were designing a runway --

Q No, I think we can come a little more closely to the facts in this case, a pipeline.

A O.K., a pipeline. What part of the pipeline do you want me to talk about, the right-of-way, or right next to the pipeline, or do you want to be very specific?

Q The area where the pipeline will be placed and the ground immediately adjacent to it.

A Well, once the pipeline is operating, and the temperatures - well, let's concentrate on the 32 degree isotherm, for example, just

above the pipe.

Q Well, can I stop you to make sure I understand where we're going?You have told us that you have this marvellous mechanism, and I'm sure it is, that predicts ground temperatures and that that's an important device. Now you've told us that one of the ways you test that out is by comparing your predictions to actual measurements.

A Yes sir.

Q All right. Now what do you regard -- you can take an example, if you want, but what do you regard as an acceptable margin of error before you begin to doubt the process?

A Well, for example, we compared -- we predicted temperatures around one of the operating test sections at Sans Sault and the pipe was operating, for example, at a temperature of five degrees, I believe, for one year, and if we looked at the temperature two or three inches from outside the pipe, and that was predicting the temperature of say plus 20 degrees or plus 30 degrees or something like that, that would certainly lead us to doubt; but if it's only a few degrees away from the pipe, that would lead us to believe that things are working properly there.

Q Well, do you want 2 degrees?

A 2 degrees? No sir.

Q Well, what do you want

before you begin to doubt the process?

A The temperature -- a very stringent test of the prediction versus the comparison, you say what do I predict at level six feet beneath the surface at day 105 after the year has started, and for example, we like to be in that case plus or minus five degrees Fahrenheit, would be extremely acceptable.

Q All right. Well now is that the level of tolerance in that situation?

A That would be acceptable, yes.

Q Now --

A Just let me finish.

Q I'm sorry.

A Now that is if we are talking about in -- once we know we're in the frozen soil or once we're in the thawed soil. By and large it's not of much engineering consequence to us in most cases to know whether the temperature is 20 degrees or 25 degrees or 26 degrees, that's not of much engineering consequence to us. In the warm ground it's not of much engineering consequence for us to know whether it's 36 degrees or 41 degrees, and that's the plus or minus five degrees.

Q Now --

A We also have to put a -- some sort of an accuracy with regard to the position of the frost front, or the thaw front, for example.

In there in most cases we can live with an accuracy of plus or minus a foot without giving us any engineering trouble whatsoever.

Q Well, I understand that some of these predictions may not concern you in the sense that they may have no engineering consequences. I'm interested at the moment in the ability of the program to predict accurately, and you've given us one measure of accuracy of day 105 at six feet. Can you give us day 105 at let us say one foot? What measure of accuracy do you require before you begin to doubt the process there?

A Near the ground surface, sir, we can't predict within plus or minus five degrees like that.

Q Well, what is the acceptable margin?

A Well, I don't really know what it is because you can really have it vary, it depends on how the snow comes off or on at any one location. If, for example, we are predicting the ground surface temperature in June of 100 degrees and we know that the air temperature is nowheres near that, that would give me some doubt. We have found that in some cases because we input incorrectly. We input at something in a factor of ten out, every time you look at your results you apply your judgment to see, are things working correctly or not, and then -- but if for example it's predicting the ground temperatures on an average

over the month of something, a few degrees away from what the air temperature is, at that location that leads you to the conclusion that your process near the ground surface is working correctly. AT any one time if you are just say two inches beneath the ground surface, --

Q No, I'm saying a foot.

A A foot, O.K., even if a foot you might be out several degrees.

Q Is it correct then, that you would not rely on this analysis for determination of ground temperatures within a foot?

A Not --

Q Unless your experience has been that it's too variable?

A Not the temperature, sir, but the -- within the top foot, for example, if we are on the Arctic coast and toward the end of the year, the end of the summer, we are predicting, say half way through the summer, if we are predicting an active layer in an ordinary soil of a foot, I would rely on that.

Q I asked you, do you have in front of you Section 8 of the application "Location Design and Capacity of Facilities"?

A What page, sir?

Q Date or page?

A What page?

Q It's the graph on page 8B137?

A Which figure?

Q At the top.

A 8B137 is the section that there is a figure attached to the other side.

Q Figure one? As I read this, the dotted line is the predicted at this site and at this location -- and at this time, is that correct?

A Yes, sir, the dotted --

Q And the straight line is the actual measurement?

A Yes, sir.

Q Now, beginning with the left --

THE COMMISSIONER: Excuse me, Mr. Scott, I'm at 8B13 --

MR. SCOTT:

Q Now, this is the prediction that was made at Norman Wells, and the dotted line is the prediction, the straight line is the actual measurement?

A Yes, sir.

Q Yes. Now beginning on the left, can you tell us the error, approximately, at the freezing point?

A Which -- the top graph or the bottom graph?

Q I'm sorry, the top graph.

A By asking me to give the error, I'm assuming that you're -- that you are assuming that the measured temperatures are spot on in that we know that it's exactly a one foot beneath the ground surface, and we are measuring it without any inaccuracy. Is that your assumption, and you're asking me to make it?

Q As you provided it to us, I'm prepared to rely on the graph. I have nothing else to rely on. Is the graph not to be relied on?

A The graph is to be relied on, but what you have to keep in mind is that you cannot physically locate a sensor -- you can predict at one foot, because you can ask the computer to spit it out at exactly one foot. When you go to measure it in the field, it's -- it is more difficult to place your thermister at exactly one foot and you also have a little bit of inaccuracy with regard to your read-out temperature measurement equipment.

The only point I'm trying to make here, sir, before I get into doing what you told me to do, is that the ground temperatures within the top foot are as difficult to measure as well, as well as to predict.

Q Do I understand you to say that you may not have been able to measure the actual temperature at precisely the location that would make it comparable?

A That's what I'm saying. There is a small margin of error in that, and there's a small margin of error on the read-out, and that just gives us a physical fact.

Q A physical fact. All right, but that margin of error is capable of working both ways, isn't it? It may reduce your recorded error, it may increase it?

A Absolutely.

Q All right. Well then, we will allow that to cancel each other out; you telling me that the error may be less than you think

it is, I telling you ah, but on the other hand it's may be more, and let's just see what --

A I wasn't trying to imply that it was going to be less.

Q No.

A I was just going to try -- I was just showing that it could be variable.

Q All right.

A Okay?

Q Now, at freezing, what is the error?

A In what, in days?

Q At about day 42?

A In day 42 --

Q It won't be 42, make it day 50.

A At day -- could you give me a number that is on the straight line there, on the line?

Q I'm sorry. I can't and make my point effecitvely.

A Okay, well let me draw a --

Q You do a --

A I will do --

Q You seem to be rather better on the even days of the year than on the uneven?

A Okay, I'll try for 50.

At day 50, this is now 50 days after September the 6th, which makes it -- around the first of December, something like that.

THE COMMISSIONER: Right. December 1st, 1971, Norman Wells. Am I at the right place and at the right time?

A Yes, you are sir.

The measured temperature is I would guess 21 or 22 degrees, say 21, would you agree with my estimation of that?

MR. SCOTT:

Q All right, I just want you to read it for me.

A Okay.

Q Tell me what you think it is.

A Fair enough. It's somewheres around say 22 degrees, and the top point is somewheres around 31 degrees, and the difference in temperature there at that time is 9 degrees.

Q And I take it that an error of that dimension appears for let us say, of that dimension more or less appears for about a month?

A Yes, more or less. That's the worst there, that's the maximum and then a month later it's about 5 or 6 degrees.

Q I think I have got a worse one than that. Let's take day 250.

A Yes, sir.

Q So it's actually 260 as we worked it out, what's the error there?

THE COMMISSIONER: Excuse me, that would be --

MR. SCOTT: On the right hand side --

THE COMMISSIONER: -- 260 days after September the 6th, 1971, so you would be into the following spring, or even summer, I suppose, from May or June '72.

A Right. The error there is -- I would estimate at 10 degrees.

MR. SCOTT:

Q I suggest to you those are two significant temperature ranges that we've looked at, aren't they, because they dictate to a certain extent whether it's melting or freezing? They're at the crucial point on the thermometer, 32 degrees?

A Well, in the one case they are just below freezing and the other they are just above freezing.

Q Yes, but in terms of predicting thaw or predicting freezing, that's obviously about as crucial a moment on the thermometer as you can get, isn't it?

A Only -- yes, for predicting freeze and thaw, sure.

Q And that is where you appear to have the maximum error in your reading? As compared to actual measurements?

A Temperature wise, yes.

Q And predicting temperatures is what this is all about?

A We are more interested in other, the difference in our predictions of the 32 degrees isotherm, rather than the difference in the temperature.

What you should be after --

Q Well, this is ground temperature, isn't it?

A This is ground temperature, yeah.

Once the temperatures move away from 32 degrees quickly, they hang around 32 degrees for quite a while.

Q But isn't this what we can --

A Can I tell you in time and days, like for example, we started predicting thawing virtually at day 30 and we started measuring thawing virtually at day 30, and that is of interest. At least that shows something with regard to predicting when thawing and -- will start, and we also -- we predict thawing starting to occur at day 240, and we measure it starting to occur at about day 250. Now I don't think that's much of a problem. It certainly doesn't bother me from any sense at all.

Q Well, that's the point I want to get. You're entirely satisfied with this as a prediction method?

A For engineering purposes, absolutely.

Q And how about for environmental purposes?

A Well, what -- I'm not sure what you are referring to there, sir.

Q We've heard, ad nauseum from all of us, that thawing and freezing will have engineering impacts in terms of the construction of your pipeline. I think it's reasonably apparent that they will have environmental impacts, the flow from those temperatures and the construction of the pipeline, isn't that obvious?

A Well, it's obvious in a very general sense, but to be specific -- but by missing the thaw, the start of freezing and thaw by one case one day and the other in ten days, what environmental problem are you referring to that you would like me to discuss?

Q I don't answer questions.

A Well I'm just asking you to --

Q Only Mr. Genest can ask me questions.

A Well, none comes to my mind.

Q Our evidence will be called in due course, and Mr.Genest will be able to --

THE COMMISSIONER: He wants to

make another point, though?

A Yes.

MR. SCOTT:

Q I'm sorry if I interrupted you.

A I was asked about the environmental implications, and it was -- would suggest that my answer was probably just directed to the engineering ones, and with regard to the point that we've been talking about, no environmental implications come to my mind, or that I have been aware of from --

THE COMMISSIONER: Nor to Mr. Scott, apparently.

MR. SCOTT:

Q Now, can you tell me either precisely or within a time frame when the Battell-Brooker or the E.P.R. programs were available for reliable application?

A Well, I think they've been available for reliable application before I joined the group, sir.

Q Well, is there any way that you can get for us that date? You joined in '73, I take it. When were they available for reliable application?

A We can undertake to get that, sir. Presumably if you'd talk to the people that wrote them, they'd say they'd be reliable very quickly. I just very early on, I'm just not sure what you mean by "reliable" on that.

Q Well, I understand the expression is after they've been "debugged" and are available to begin precise prediction, on your project.

A We can undertake to get that for you, sir.

Q Is anybody prepared to estimate, because there are certain questions that follow this? Does anybody know when this process began to be utilized?

WITNESS WILLIAMS: The E.P.R. program became available to us, I think, in 1971. Now what kind of shape it was in at that time I can't answer that. But that's about the time the deal was

put together with Esso Research.

Q How about Battell-Brooker, would that be about the same time?

WITNESS MORGENSTERN: I think I can comment. It drew very much on some research and development with the University of Alberta, the main backbone of the program was conceived and working about that time.

Q Yes.

MR. GENEST: Is that good enough, Mr. Scott?

MR. SCOTT: Well, to let you off the hook, Mr. Genest, I think -- I'd like your assurance that those are the dates.

MR. GENEST: All right, we'll check that.

MR. SCOTT: And I think we'd also like to know from how many test sites did you have data for the ground temperatures prior to the introduction of the two programs?

WITNESS WILLIAMS: We gathered that temperature data around the pipeline at Sans Sault in March 1971.

Q Yes. Well, what I'm interested in, and perhaps I can make it more clear, is when did you begin to collect the recorded temperatures, the actual temperatures that you then attempted to predict?

WITNESS SLUSARCHUK: Well, in

the reports of all the test-sites -- the Sans Sault, the Norman Wells, and the Prudhoe Bay -- it says exactly in those reports when they started collecting the data, sir, and we could do no more than just take those numbers out and give them to you.

MR. GENEST: Mr. Commissioner, I wonder if I might make a suggestion to Mr. Scott? It may not be welcome, that there is a number of technical data that perhaps his staff advisors could confer with ours to find out some of these very detailed and technical matters which might -- it seems to me might save a lot of Inquiry time and perhaps satisfy some of the concerns that obviously Mr. Scott is transmitting in his cross-examination?

MR. SCOTT: I think the point of this question can be made clear. If we go back to the diagram to which I referred earlier, that is figure 1 of 8-B-137, and this applies basically to all the graphs that are shown, figure 1 at the top attempts to predict a period of days following September 6th of 1971. What -- is that correct?

A Yes sir.

Q What I want to know is first of all, when that data was collected and when the prediction was made?

A I'd have no idea. We'd have to really search the records to get something like that. But if that's what you need, we'll make the attempt.

Q Because I am not suggesting any bad faith at all, but you would be familiar, Dr. Slusarchuk, with a program into which you insert quantities of data, some of which has a variable factor and has to be manipuated as the program develops. If you already know the figures that are to be achieved, that is if you already know the actual figures, there may be a very human tendency when the predicted figures are produced, to alter the data put into the process, rather than to conclude that the process simply doesn't work.

A We have taken these figures right out of reports that were prepared by, in this case in the Norman Wells test facility, prepared by Brooker & Battell, in their report,and I can refer you to that report. There are a great number of other predictions in there. We just picked out one to put in there.

THE COMMISSIONER:

Q The point that is made is this. Were the actual measurements available before in fact it was sought to predict? In other words, was it the prediction made after the fact? That's what the question is about, isn't it?

A I would guess, sir, that probably it was.

MR. SCOTT: Well, to follow that up I would like to know if you can show us any prediction that was made prior to the measurement of the actual ground temperature changes?

A Well, any temperature that was predicted prior to the --

Q Can you show us a graph of predictions in which it can be said that the actual results were not known at the time the prediction was made?

A Yes sir, I can show you -- not for around the test site but for around thermister strings in the ground, we can show you a bookful of those.

Q Well, perhaps to save the time of the INquiry, you can produce whatever graphs you have that, upon your assertion, predictions were made in advance of the time -- I mean real predictions, that is predicting the future.

A Yes sir. Well, what we have done, and I can refer you to the exact one right now because we have them listed here.

Q I predicted the future when I said I'd only take two or three days, looking back on it I could now predict that I think I will be five or six before I'm concluded.

MR. GENEST: I don't find that a helpful observation.

THE COMMISSIONER: I wish we could go back and make his first prediction come true.

(LAUGHTER)

MR. SCOTT: That's an opportunity I don't have, you see; the input data are fixed.

A I seem to put my finger on it, but it doesn't quite meet your two requirements in that we had the data within N.E.S. and we asked -- the data was there, it was data from 1971 and 1972, and we had that data in house, and we wanted to see how well we could predict, and we asked Battells to take on the assignment of just knowing the bore hole stratigraphy and from pictures to predict temperatures, and off they went and they predicted some -- temperatures from some 30 bore holes. Now all you've got is my word and possibly some correspondence where they would acknowledge that, and I could dig that out for you, too.

Q I'd be grateful.

A That that was the case, and then we gave them some more, some more holes on the same basis, and we can give you that information.

WITNESS MORGENSTERN: I might comment on that, Mr. Scott, in my task as reviewer, of some of the activities of N.E.S. involved in that and the object of that exercise was indeed to satisfy skeptics like myself that the predictions could be made to a reasonable degree of accuracy, so that Battell were doing it as though the data had not been collected. They were not privy to the actual measurements.

Q Were you satisfied, Dr. Morgenstern?

A Reasonably.

Q You exhibit some hesitation there. Is there any or am I mistaken?

A Sorry, hesitation about the reasonableness?

Q About the extent of your satisfaction.

A Oh, I am sure that we can predict the position of the freezing or thawing front to the engineering needs. We don't predict temperature fields particularly in thawed soils to a high degree of accuracy. That's not engineering, and I think not of environmental consequence.

Q Well, just so I'm clear, do you agree with the observations that Dr. Slusarchuk has made?

A Yes.

Q Do you have any hesitation in adopting his observations respecting the input data? And the ambiance of error?

A Well, if I --

Q Well, it's the best I can do, Mr. Genest, as I've had two long days. Ambit of error, I think I mean.

A I'm less hesitant than he about some of these things. On average, the energy balance of the earth's surface has about 20% involved in long-wave radiation, and a 10% variation in green house factor would make about a two or 3% variation in long-wave radiation input, and that would then have a

small percentage effect on the key thing we're interested in, which is the position of the freezing front. So that issue doesn't bother me.

The central issue about error is that the accuracy of our prediction is more acceptable the further north you go, and less acceptable further south, that the reality of the situation is that we're less in the discontuous zone than we are in the continuous zone.

Q Are you able to hazard --

THE COMMISSIONER: Excuse me, Mr. Scott, I'm sorry. Would you mind repeating what you just said in the last couple of minutes, Dr. Morgenstern?

A Yes. If I make a hundred percent error in predicting the depth of the active layer in the continuous zone further north, since the active layer is relatively thin, then I'm only predicting that perhaps a variation of a foot, but that 100 percent error further south is now many feet or several feet, so that the --

Q When you say predicting the depth, you're speaking of the recession of the frost front?

A Well let me suggest the following scenario . We come and do some disturbance along the right- of-way and that changes the energy balance, and leads to a thickening of the active layer. A hundred percent error in that prediction would only be a foot or so, 18 inches in the continuous zone --

Q The depth of the active layer?

A Yes, the thickening of it. But it would be several feet, perhaps three, four, five feet in the discontinuous zone.

Q Yes.

A So that the percentages might be the same, but the physical implication is

more worrisome further south you go.

WITNESS SLUSARCHUK:

A Perhaps Mr. Scott, I could just tell you which references I am referring to. In our testimony they are references number 148 and 143 --

MR. SCOTT:

Q When you say in your testimony, do you mean in the book?

A Yes sir, in our -- Appendix B of our canned testimony, it's numbers 148 and numbers 143.

THE COMMISSIONER: Well, I think we will take a break for coffee, if that's all right, Mr. Scott?

(PROCEEDINGS ADJOURNED)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT: I've shortened down some questions I have, and it may be that we can complete this afternoon in about 10 minutes, if you please. In order to get the panel and others back to their places of origin tomorrow, Mr. Genest has suggested, and I think it's satisfactory unless some other counsel objects, we should stop at 12, but in order to do that and not to lose any time, we're prepared to begin at eight.

Does anybody object to that?

The press has indicated a modest objection which we can ignore.

THE COMMISSIONER: Well --

MR. SCOTT: Will that be satisfactory, sir?

THE COMMISSIONER: Well, eight o'clock.

MR. SCOTT:

Q Now Dr. Slusarchuk, in terms of -- you outlined for me the problems connected with assessing the margin of error for individual input data into the program. Have you considered -- have you given any consideration to the acceptable margin of combined error, in terms of input data?

WITNESS SLUSARCHUK:

A Well, our -- we don't have a number like that, sir. We don't have the individual errors for the individual parameters and we haven't tried to combine errors to get some kind of statistical average of error. Our only guiding -- our only guiding concerns on this is that with numbers that we are using, are we predicting what we are observing in the field and when we change these numbers, say from an ice rich silt to a non-ice rich silt, does it predict what we understand that has happened from things that have been reported in the literature and what we have measured ourselves.

Q Do I understand that to mean that your concern is not focused on the margin of error of input data, but has rather focused on

whether the predictions prove out?

A We've -- that is mainly correct, although we have put quite an effort into compiling what we felt was a very good set of input parameters but we did not go to the next step and put errors attached to each input parameters.

Q Well now, at page A2-4 --

A Which --

Q It's the report that deals -- the blue covered report. Do you have that?

A No sir, I don't.

Q Well, let me lend you mine. You'll see a passage underlined at the bottom of A2-4, which reads as follows and I quote:

"The Greenhouse factor has been measured and appears relatively constant".

A Yes, sir.

Q could you tell me what you understand by that observation?

A It means that the value of it doesn't fluctuate very much from year -- from season to season, and from latitude to latitude as we go along our several hundred miles of pipeline. That's what it means to me, sir.

Q Thank you. Now, I take it that the -- it's perhaps obvious at this stage that the geothermal calculations that are obtained by this process are going to be used in the design of the pipe, that is to say, in determining its location

from place to place?

A It will form one of the inputs to that design, sir.

Q Yes. Are you -- have you any familiarity with what I understand to be called the worst likely circumstance concept in determining input data?

A Not in that sense, no, I can imagine perhaps what it means. I'm not familiar with that sir, nor with any sort of writings on something like that.

Q Do you know whether that concept has been given any consideration in determining the input into this program?

A That concept hasn't been used in putting together the input parameters that we have put together in the applications of geothermal analysis, sir.

Q Well, one question that a member of one of our attendants has asked me to put, that is one of the residents, and I think it may have been dealt with earlier, though I have been unable to find any reference in the transcript. Assume that the pipeline crosses an ice wedge at approximately right angles. The concern expressed is this, that from time to time a sudden cracking of the ice will be heard in cold weather at that location. What is that sound which is attributed to the ice wedge, at least by the questioner, and what is its effect, if any, on the pipeline?

A I think that somebody other than myself can answer that.

WITNESS McROBERTS: Well, there are two questions, I guess. The first one is, "What's the cause of the sound?" My understanding is that the sound is caused by the ice cracking, as the ground contracts.

The second question relates to whether or not there is any influence on the buried pipe, and there is, to my way of thinking, no influence.

However, I think I should probably explain to you why. Before I do that, though, I think in order that my explanation would be understood, I'd have to explain very briefly how ice wedges form. I think that might partly explain the noise as well.

Dr. McKay, as I understand it, has described the process of formation of ice wedge features. They are caused by shrinking of the permafrost as it cools during the winter. In order to get the crack forming in the ground, you need a considerable amount of change of temperature, and a cooling to a very low temperature. That's why in fact you only find active ice wedge polygons in what we would call the continuous permafrost zone because it is relatively much colder than any of the more southerly or discontinuous permafrost zones.

We do find old active -- we find old ice wedge polygons in the discontinuous zone, mind you, but they are no longer active.

Now the cooling that occurs is restricted to the upper part of the permafrost, and the amount of cracking is related to the change in temperature. For that reason, ice wedges crack more at the surface where there is more temperature change and to a lower temperature than they do with depth. For that reason and exactly for that reason is why you end up with a wedge.

Now in our pipeline we will -- we are proposing to operate any given section of

pipe, say a specific spot in the pipe with time will be operated at a constant temperature, and that constant temperature in the pipe maintains the soil around the pipe, there's a bulb, if you will, not of frost but of constant temperature. If you can visualize a 4-foot diameter pipe below the pipe extending for a depth of I would say five to six feet, there will be no real change in the temperature of the permafrost whatsoever, and it would be maintained at the temperature the pipe is operated at. To either side of the pipe, the temperature is out to a distance, I would say, of two to four feet It would not fluctuate say more than about a degree.

For that reason then the pipe itself is maintained, the soil around the pipe is maintained in a constant temperature condition and therefore it can't crack. So that while you may be going through ice wedge polygon terrain that may be active, the influence of the chilled -- excuse me, the consequence of the chilled gas pipeline maintaining a constant temperature bulb around the pipe means that cracking doesn't occur to the pipe. The ground -- the permafrost terrain away from the pipe will continue cracking as it normally did, and the soil immediately around the pipe will not crack any more because there is no temperature change.

Q Assuming this ice wedge, do I understand you to say that that situation will not produce any damage to the pipe?

A Once the pipe is in operation there will be no temperature change around the pipe and therefore no crack.

Q Yes, and I take it that if that phenomena repeats annually, there will still be no damage.

A No, because there will be no increase -- the ice wedges grow on an incremental basis up to, studies by Ross McKay and others, maybe up to an increase in thickness of an eighth of an inch a year. Now that -- not every year, necessarily -- that will occur in the permafrost terrain on either side of the pipeline, but for the permafrost around the pipeline, it is maintained in a constant temperature situation and nothing will happen to the pipe because there is no cracking.

Q So you say that if the -- if after chilling, it happens once or if it happens -- you say that after chilling it will not happen, the cracking will not occur.

A That's correct, yes. Now there have been some studies done in Alaska on exactly this problem where a buried pipe was put in the ground, about 1,000 feet of 40-42-inch line was put in the ground, the pipe was not in operation, just what we would call an inactive test facility. The pipe was put in the ground and there was in fact cracking that occurred and there was no significant stresses or strains thrown on the pipe.

Q Well, I was going to ask you what happens in the period of time before the pipe is chilled, if this phenomena occurs?

A Well, as I suggested, we do have a fairly well documented case record in the literatures that shows it's of no concern. One also has to keep in mind that the loading on the pipe, when the pipe is buried in the ground, generally speaking the pipe will be in compression when it's in the ground.

Now, you have to -- it's difficult -- I have to just explain this. When the pipe is strung together above the -- welded together, this will be done by and large in cold temperatures, especially during winter construction in the continuous permafrost zone, the pipe will be very cold. It might be the temperature of minus 40, minus 30, and I'm thinking in degrees Fahrenheit, when the pipe goes into operation, it would be at a temperature as low as 10 degrees Fahrenheit or warmer, depending on the location downstream from the compressor station.

Therefore, the pipe itself would tend to expand in the ground because of this. It can't because it's fixed, it's a restrained pipeline, but the strains in the pipe would be in a compressive sense.

During, prior to start up of the pipe, if an ice wedge cracked, the tendency would be to instead of putting the pipe in compression, it would start to put it in tension, but there is a --

apart from the fact that the pipe could take it any-ways, it's prestressed in the other direction as a matter of circumstance in relationship to the pheno-mena we are talking about and the temperatures between installation and operating conditions.

It's that fact and the studies that were undertaken in Alaska that were, to my way of thinking, a document to substantiate the fact there would be no design problems associated with ice wedge polygon formation.

Q I take it that you're aware of the report of Keith J. Anderson and Associates entitled "Burial of a Cold Pipe in Wet Permafrost"?

A No.

Q Well, in that report, and I'll have to tender it as an exhibit, though it comes from my friend's library, the report analyzes the 42 inch pipe which crosses an ice wedge at 45 degrees. It is assumed that the ice wedge cracks as the ground contracts with cold temperatures, and the authors say,

"Since the shear forces are in the same order of magnitude as the shear strength of the pipe while the displacement is only point 18 inches, we concluded that the pipe might not break but would certainly deform. These forces reported annually would eventually produce progressive failure. Again, no

quantitative data was available, but the results of these calculations indicated the conservative limits of a potentially severe problem".

A Well I wouldn't agree with that comment at all. First of all, the amount of load that could be thrown on the pipe is governed by the backfill around the pipe. Now, in the worst conditions that one could conceive of is that the pipe would be completely surrounded by ice. By and large, what we would be doing is digging a ditch and putting the native backfill back into the ditch. And for the time involved prior to start-up, the pipe would be held, it would be surrounded by loosely compacted backfill that may have thawed and refrozen here and there.

And the upper limits, the amount of load that could be transferred between the contracting soil and the pipe, would in my estimation be no more than about 60 or 70 pounds per square inch, and that certainly is nowhere near the limiting capacity of the pipe.

I wouldn't agree with that report at all. I've never read it, the passage that you've read to me.

Q In the Alaska case do you know whether the pipe remained intact?

A Yes, there's a paper published by a Professor George Knight of the Institute of Arctic Environmental Engineering at the

University of Alaska. It was published in 1971, the proceedings of the Symposium on Cold Region Engineering, put out by the University of Alaska, and he -- his -- he was measuring the deformation associated with ice wedge cracking in the pipe, and he commented on certain levels of strain.

My understanding is, and my input, and this is purely from a geotechnical point of view in talking to our mechanical stress analysis people, that the amount of strain that could possibly be thrown on our pipeline prior to it going in operation are quite acceptable, and after the pipeline goes into operation, there is no problem.

Q In the Alaska case, do you know whether there was deformation or not in that reported case?

A Yes, the deformations that were measured and commented on by Professor Knight, he -- in one of his conclusions states that the maximum transducer strain recorded as applicable to an ice wedge crack, was 270 microinches per inch.

Q Well now, what does that mean? Were there deformations in the pipe, or were there not?

A There was some slight deformations in the pipe but they were well below the capacity of the pipe, and I further understand from discussions that -- one of my colleagues at Northern Engineering Services has had with people in Alaska that the state of affairs as reported in 1971

to now hasn't changed. There's no adverse loads thrown on the pipe.

Q Is that your view also, Dr. Morgenstern?

WITNESS MORGENSTERN:

A Yes, sir.

Q You adopt what Dr. McRoberts has said?

A Yes.

MR. SCOTT: Mr. Commissioner, would this be a convenient time?

THE COMMISSIONER: Yes. May I ask if it is likely that the examination of this panel will be completed tomorrow if we sit for four hours tomorrow?

MR. SCOTT: It's unlikely.

THE COMMISSIONER: Well, there's not much we can do about it, I suppose.

Well, we will adjourn then until 8 o'clock tomorrow morning.

(PROCEEDINGS ADJOURNED TO 8:00 A.M., FRIDAY, APRIL 11TH, 1975)

Mackenzie Valley pipeline inquiry:

Vol. XXVII 10 April 1975

MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF AN APPLICATION BY CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES FOR THE PURPOSE OF THE PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Honourable Mr. Justice Berger, Commissioner)

Yellowknife, N.W.T.

April 11, 1975.

PROCEEDINGS AT INQUIRY

VOLUME XXVIII

ALLWEST REPORTING LTD.,

APPEARANCES:

Mr. Ian G. Scott, Q.C. Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Inquiry;
Mr. Pierre Genest, Q.C. Mr. Jack Marshall, Mr. Darryl Carter and Mr. John Steeves	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs, Q.C. Mr. Alan Hollingworth	for Foothills Pipelines Ltd.;
Mr. Russell Anthony, and Prof. Alastair Lucas	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton	For Northwest Territories Indian Brotherhood and Metis Association of the Northwest Territories;
Miss Lesley Lane	for Inuit Tapirisat of Canada and The Committee for Original Peoples' Entitlement;
Mr. Ron Veale and Mr. Allen Lueck,	for Council for Yukon Indians
Mr. Carson H. Templeton,	for Environm ental Protection Board;
Mr. David Reesor,	for Northwest Territories Association of Municipalities;
Mr. Murray Sigler,	for Northwest Territories Chamber of Commerce.

I N D E X

Page

WITNESSES FOR APPLICANT:

April 11, 1975.

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR SCOTT: Good morning. Mr. Bell isn't here yet but I presume we can proceed in his absence.

JOHN IVOR CLARK
GARRY WOOD HOLLINGSHEAD
EDWARD CHARLES McROBERTS
WILLIAM ALEXANDER SLUSARCHUK
NORMAN REUBEN MORGENSTERN
RICHARD H. COOPER
R.M. HARDY
GUY LESLIE WILLIAMS, resumed:

CROSS-EXAMINATION BY MR. SCOTT (CONTINUED):

Q Dr. Cooper, I'd like to ask some questions dealing with the general question of northern rivers, and we mean by this principally rivers on the North Slope. I take it it's your position as stated on page 2633 of the transcript of March 20th that there is virtually zero flow, that's your phrase in quotations, "virtually zero flow in the rivers of the Yukon North Slope during the winter."

WITNESS COOPER: We have done some work in attempting to measure flow or find flow, and there is very little flow beneath the ice. So shall I say it's very, very low.

Q Well, it's virtually zero, isn't it?

A Yes.

Q Dr. Clark, on page 2633 of the transcript -- I'm sorry, Dr. Clark, on page 2623 of the transcript, Volume 22, you were asked

this question by Mr. Anthony and gave this answer. Let me read it to you:

"Q And we have discussed in the evidence before this Inquiry about flow characteristics of such rivers as the Malcolm River, for example, on the North Slope of the Yukon. Now I believe that as a result of those discussions I'm accurate in saying that in those rivers, for example, or in that river, for example, dealing with it as an example, that in winter often it is freezing right throughout at certain portions through the whole depth of the river.

A I would think that in certain braided portions that would be the case, yes."

Now that was your question and answer. Would you agree with me that the phrase "in certain braided portions" that you used includes probably something between 90 to 100% in the rivers in the vicinity of your crossings?

WITNESS CLARK: I'm not clear what you're asking me to agree with.

Q In your answer you said that in the winter freeze on the North Slope in river beds extended throughout the whole depth of the river in certain braided portions. I accept that answer, I have nothing to quarrel with in it. What I would like to know is, would it be fair to say that 90% to 100% almost of the rivers where you cross are at

the braided portion?

A Yes.

Q And that they are therefore frozen, as your answer indicated.

A Yes. My answer, what I meant by "braided portions" there was that there could be some braids, if you like, that could be carrying water.

Q But that would be relatively unusual in terms of numbers of braids during the winter.

A I believe it would be unusual, yes.

Q And that same observation, I take it, would apply to almost all rivers and small streams on the Yukon North Slope.

A Yes.

Q Well, Dr. Clark or Dr. Cooper, would you agree that there is likely to be permafrost at some depth under most rivers of the Yukon NOrth Slope?

A Yes.

THE COMMISSIONER: Permafrost at some depth, or to some depth?

A It would be at some depth, sir. I think I gave an example earlier that for a 200-foot wide stream, I would expect to hit permafrost 40 to 60 feet below the bed.

MR. SCOTT:

Q I thought that was the

position and I'm somewhat mystified by the statement in the canned evidence at page 4, the second paragraph, it may simply be a misprint.

Q Do you see it? The second sentence it says,

"Because of the freezing temperatures of the water, however, permafrost does not exist beneath the beds of the larger rivers, even along the Arctic coast."

A That's correct.

Q Yes, well what river -- is that not inconsistent with the other answer?

A Not entirely, the permafrost would -- for instance / does not exist at certain channels of the Mackenzie River.

Q Well that isn't what I understood to mean the Arctic coast, obviously it flows into the Arctic coast. Are there other rivers apart from the Mackenzie in which in your judgment there is no permafrost on the north slope?

A We haven't drilled any of the river beds along the Arctic coast. I'm sure you are thinking of the Yukon and Alaska.

Q Well let me ask you this: Apart from the Mackenzie with which we've dealt, I think in another context, would it be a prudent assumption that there is permafrost at some depth below the beds of all other rivers that flow into the Arctic in the area with which we're concerned?

A At some depth, yes.

Q Well I've got a slide show. It's a very amateur drawing, not as amateur as the

focus makes it appear, and I would just like to understand if I can, the mechanics if that is the phrase that applies to the operation of North Slope rivers of the type I have been discussing. Now you see on the diagram, Dr. Cooper, Dr. Hollingshead, ignore # 7 & B for the moment, that a small river bed is shown both in June and in March.

Now, the diagram for June shows water in the channel permafrost line and with the pipe passing through. I take it that is a fair representation of a typical situation at that time of year?

WITNESS COOPER:

A Yes, I think so. That just shows a single channel rather than the braided nature, for conceptual purposes, yes.

Q Now, the second diagram shows the river, let us say in March, and you have told us that the river has either dried up or frozen, and that would be typical for a channel of that type would it not?

A Yes, I think so. Can I

ask a question?

Q Yes.

A You mean so you've got a limit of frost, you have essentially a frozen window or a thawed window in there now.

Q I'm sorry, Dr. Cooper, I didn't get your answer.

A Well, I think -- could you explain on the March one, which portions are thawed and which portions are frozen?

Q Well first of all, on the March one, I'm looking at the river bed, and I understand that it would be either dried and full of snow and ice, or frozen -- almost to the bottom?

A Yes, and to a depth of possibly a few feet.

Q Below the river bed?

A Right.

Q Yes. And that the red dotted lines below the pipe and immediately above the pipe, show a frozen area that would typically exist?

A Well, they show a boundary between a frozen and a thawed area.

Q Yes. Well, I take it what you're saying to me is that the permafrost line remains as it did in the previous diagram?

A That's correct, and just above your finger would be thawed.

Q Yes --

A Above and to the left of

your finger.

Q And there is a frozen araa around the pipe?

A Yes.

Q Yes. Well now, this is designed to show the same river in I think it's called longitudinal section , would that be correct?

A Yes, sir.

Q Yes. And does that disclose the same thing? The dotted line or the hatched line at the top in the June diagram represents the river bed, and above it is whatever water is in the river at June?

A That's correct.

Q Yes. Below that is the ground that is the river bed and the soils below it --

A That's correct.

Q -- in which the pipe is placed? And around the pipe with the red dotted line, but above the permafrost line is the frost bulb?

A That's correct.

Q And on the left there is a designation ground water, and I take it/it is typical that ground water will percolate through the soils below the river bed?

A That's correct.

Q Yes. And that would be a typical situation in this kind of river looked at in

that section in June?

A That's correct, yes.

Q Now, can we come to March. I take it as we have there a longitudinal section and I take it that above the river bed and probably contiguous with it will be snow and/or ice in some mass?

A Thats correct.

Q Yes. Again, we have the top limit of frost which is frost that is coming down from the snow or ice in the river bed, which is the top red dotted line, would that be correct?

A Correct.

Q Then in unfrozen soils we have the pipe with its frost bulb.

A Correct.

Q And below that the permafrost line.

A Yes. Could I just add something at this point?

Q Yes.

A The distance below the bottom of the frost bulb and the permafrost line appears on your sketch to be very minimal. Now we don't know in all instances where the permafrost table will be, and of course that will be relatively constant. However, I'd also like to point out that we are recognizing that in some instances we will have shallow bedrock and a relatively shallow aquafer, which would essentially give the same effect that you're talking about, and we're recognizing that problem of possibly confining that aquafer.

MR. GENEST: Mr. Scott, it says "limit" at the bottom right-hand corner. There seems to be a squiggle or dot. Is that seasonal?

MR. SCOTT: It should be "limit of seasonal frost". I think that's an "S" with some little symbol indicating the balance of the letters.

Q Now, I'd like to refer you to the applicant's reply to question 38 posed by the Assessment Group. It's page 38-5, do you have

that, Dr. Hollingshead? Or 38-5 is the portion of the reply that I want to deal with.

Now, do I understand correctly that this reply to question 38 is based on the Battell Report of October, 1974?

A I think Dr. Clark can better respond to that.

WITNESS CLARK: That's my understanding, yes.

Q And that the last one of the problems that are dealt with in that answer, that is 3.3 at page 38-5 -- do you see that?

A Yes.

Q That that last of the pipe below river problems that is dealt with in the response, the one that deals with rivers that freeze to the bottom is the relevant answer for virtually all small and intermediate crossings.

A I'd have to re-read that.

Q Well, Dr. Cooper, have you had an opportunity to look at it?

WITNESS COOPER: I am just reading it right now, sir.

MR. GENEST: Mr. Scott, you mean it is an relevant answer for all streams that freeze to the river bed?

MR. SCOTT: Yes.

A I think we could state

that that type of river is typical of braided rivers that we're crossing, I don't think there's any dispute there.

Q Do you agree, Dr. Clark, or do you -- have you not finished reading?

WITNESS CLARK: I was reading while Dr. Cooper was making his comment. I didn't hear what he said. If you're asking is this typical of North Slope small streams, yes.

Q Is this the answer that will apply to, if not all, almost all the streams and channels that enter on the North Shore, or that exit on the North Shore?

A That they would freeze to the river bottom, yes.

Q Yes, and this answer applies with respect to that problem.

A Yes, it does.

Q Now is it correct that the computational results of the Battell Report depend on the type of materials that existed under the river?

WITNESS SLUSARCHUK: Yes sir.

Q And I take it it's also correct, reading the Battell Report, that they had to make assumptions about the soil conditions, about the type of materials below the river because there was no drill hole data for most of those rivers.

A This is correct, sir. When we were doing these analyses with Battell, we

did not have drill hole data and we did make assumptions with regard to permeability of the soil, and we varied it from fine-grained material to coarse-grained material.

Q And isn't it correct to say that in their report, Battell also had to make other assumptions or achieve simplifications of their definition of the problem in order to prepare a response to it?

A They were some of the assumptions. The other major ones with regard to flow would be the slope, and that was not an assumption. We had measured data on the bed of the slope that we input into that.

Q Yes, but I take it for example in order to respond to the problem with the knowledge they had, they -- and I think they perhaps conceded this -- they ignored the pressure rise which would occur upstream of the growing frost bulb.

A In this case, yes sir.

Q Yes, and as a consequence in developing a model to which they could respond or which they could analyze --

A Excuse me, sir.

Q Yes.

A I was incorrect. That was not -- we did not ignore the pressure completely. We didn't consider it a confined aquafer, and from that point of view we ignored the pressure; but we did

take into account the pressure difference at where the water was flowing past the bulb, and that as the bulb -- the frost bulb enlarged and started to close off more and more of the aquafer, we reduced the rate of flow accordingly,according to pressure loss, but not according to a confined -- not assuming that the top was frozen. We assumed that the water table could just go up to the ground surface.

Q Well, I make no criticism of it, but would it not be correct to say that the Battell computational results are a speculation based on a model and on a variety of assumptions?

A It's our -- I don't think "speculation" is a fair word, sir. We -- Battell actually just carried out the analysis. We were the ones that laid down the various input parameters that we wanted run. They developed the convective portion of the model and ran through the mechanics of putting the numbers in and coming out with a solution. But it's not speculative in the sense that we just put any numbers in. We put in very rational numbers.

Q When I said speculative, I was perhaps unfair, I didn't mean to suggest absolutely random, which I think is the point you're making, but it was a judgment based on a model based in part on some necessary assumptions?

A Yes, sir.

Q Yes. And I put it to you that therefore it can -- the conclusions of Battell can really only be accepted as fact after they have been tested in the field?

A We don't have any field evidence or field data that would confirm the results that we've got here. That is correct, sir.

Q Well I take it that as we were saying yesterday, that when you took Battell's geothermal analysis, you were able in the way you described yesterday, to effect some tests in the field to ascertain the accuracy of their analysis with respect to the geothermal problem?

A Yes, sir.

Q I take it that you would want to do the same with respect to their analysis about these rivers, if it were possible?

A Yes. We did make a couple of tests to make sure that the computer program that was developed was working correctly. We compared that and this is given in that report. We compared it with a close form solution for a convective model of water flowing through soil to check whether the model was

handling the convective component correctly, and it was. So this gave us confidence that the convective model was -- computer model was working correctly.

Q Yes. Is there -- and we have been unable to find any, is there any report or analysis of that test?

A It's in the Appendix of that report that you're referring to, the Battell report, sir. At least to the best of my knowledge it's in there. I'm sure it must be.

Q Well I take it that generally speaking with Battell, you have attempted to test and, as you indicated yesterday, their results in the field, where possible?

A Yes, sir.

Q Has it been possible to do any of that field test with respect to Battell's results related to this problem?

A No, sir.

Q No. And I take it that you have no plan for a sort of a test river crossing on the north slope?

A Not right at the moment, sir, no sir.

Q Is any plan in the works for such a test river crossing?

A No, sir.

Q Now Dr. Cooper, in a report made by T/ Blench and Associates Limited, called "Breakup Observations on Northern Rivers of 1973",

made in June, 1973, there is a statement I wish to read to you. You're familiar generally with that report, are you?

WITNESS COOPER:

A Yes, it's been some considerable time since I've reviewed it.

Q Yes. And it was made by Mr. Nuttall of your firm?

A That's correct.

Q On page 20 of that report, under a heading "Discussion of Aufeis Observations", A-u-f-e-i-s, Mr. Nuttall says, and I quote:

"Growth of the frost bulb around the pipe in an unfrozen aquifer could conceivably restrict seepage flow and build up damaging pressures".

Do you agree with that observation?

A Damaging pressures, I believe Mr. Nuttall refers to as pressures that would cause surfacing of the water, and addition to the icing. Not damaging -- he doesn't mean it as damaging pressures to the pipeline.

Q With that qualification, do you accept the rest of his statement?

A Yes, if the permafrost configuration was such that the constriction of the ground water did occur, yes.

Q You've said that the qualification you add is that it is damaging if the -- if it rises above the water bed. What's damaging

about that?

A Well that's my qualification, I don't think I would use the word "damaging". I think I would use the word that excess pressures would be built up, or the wording that excess pressures would be built up, and this would cause a surfacing of the water.

Q Is there any -- assuming the pressures build up in the way that Mr. Nuttall has described, can any damage result from that, to either the pipe or the environment?

A No, I don't believe so.

Q What is the consequence of the build-up of those pressures?

A Well I'd like to also point out that we have proposed a solution to alleviate those pressures and pass water through.

Q That's the hole in the pipe that --

A The insulated pipe, yes.

Q We'll come to that in a moment, and obviously if you have a solution there aren't going to be any pressures and there isn't, to use Mr. Nuttall's phrase, as qualified by you, going to be any damage if all that works. But if that solution were not devised, what is the damage that would result from these pressures, or is there any?

A Well, what would result is you would get water surfacing upstream of the pipeline, which is the mechanism by which these

icings develop naturally.

Now, the presence of the constriction due to the frozen pipeline, would be to cause the icing to grow upstream.

Q Well now, Mr. Nuttall goes on, and perhaps I should read the whole paragraph, so you'll have it. It reads as follows:

"Growth of the frost bulb around the pipe in an unfrozen aquifer could conceivably restrict seepage flow and build up damaging pressures. This problem has to be studied by means of drill holes and temperature observations wherever sub-soil seepage occurs. Aufeis deposits on or downstream of the route marked possible sub-soil seepage".

Would you agree with that observation, bearing in mind the qualification you've attached to the word damage?

A Well yes, of course. WE would be investigating the crossings to determine the thickness of the aquifer by bore holes.

Q Well now just so we'll be clear, the problem we're talking about, I take it, is -- relates to the ground water.

A Yes sir.

Q And what is happening is that the ground water would, in the absence of the pipe, would percolate along here, in due course coming to the surface at various places.

A Yes, and causing icings naturally.

Q Yes, and that what has happened is that between the -- in the winter, in the March example, between the level of frost below the river bed and the permafrost, the pipe has been inserted.

A Yes, in cases where the permafrost is that shallow, that would happen.

Q Yes, and around the pipe has grown a frost bulb.

A That is correct.

Q And the result of that may be if the dimensions are right, that the Templeton Wall, which is the frost bulb, insofar as it extends between the frost line below the river bed and the permafrost line, may block off that ability to see.

A Only in those cases

where we consider it not necessary to put the cross-drainage in.

Q Yes. I'm just trying to analyze the mechanics of the problem and then we'll come to the solution; but the problem is that the Templeton Wall may effectively prevent the seepage in certain cases.

A Yes sir.

Q And I take it that then you do agree with what Mr. Nuttall has said, that the problem has to be studied by means of drill holes.

WITNESS CLARK: A If I could add a comment, sir?

Q Yes, certainly.

A Our proposal is not to restrict ourselves to bore holes in studying that problem.

Q What other solutions are contemplated in order to study the problem?

A We're contemplating a geophysical survey there as well.

Q Well --

THE COMMISSIONER: Contemplating what?

A A geophysical survey.

MR. SCOTT: In this context then with relation to those rivers, what is a geophysical survey?

A It could be resistivity

or it would likely include resistivity surveys.. It could also use shallow seizmic surveys.

Q What is the first kind of survey?

A It's a survey that's a very common technique that employes an electrical device where a current is passed in effect through the earth.

Q Is this in effect shallow seizmic blasting in the river?

A Oh no, it's -- there is no blasting at all associated with either of the techniques that I've described.

Q So I take it then that you have that potential technique, you have the technique of soundings.

A Yes.

Q Will soundings help you tell where the permafrost is?

A Not soundings, no.

Q Will the first help you tell where the permafrost is?

A The geophysical survey?

Q Yes.

A Yes, it will.

Q And then you have the possibility of drill holes.

A Yes sir.

Q And I take it that those

techniques are designed to give you in every concrete case where it's required the kind of dimensions that are shown in the two diagrams I've put before you.

A That's our expectation, combined of course with reconnaissance, the types of observations that will be made over this year and other years by others as well as ourselves.

Q Well now, I take it, Dr. Clark, that the problem that we have been analyzing is not limited to minor river crossings, but also applies to the Malcolm and Firth Rivers.

A Indeed it does, yes.

Q Yes, and I take it that on page 14 of the -- of your canned evidence, the addendum, actually, --

A Page 14 of the addendum?

Q Yes, it's a response to one of the Assessment Group's questions, you say in the first sentence:

> "It is agreed that operation of the chilled pipeline by itself could induce new icings at some minor river crossings."

I take it that that -- the effect of that when understood is to include the Malcolm and Firth Rivers.

A It could induce some icings, yes.

Q And with the exception of the Mackenzie leading into the Arctic, it's a problem that applies basically to all the rivers,

exiting on the North Shore.

A All the gravel bed rivers, yes, where there is winter flow in the bed.

Q And minor is only a comparative term in this context, as compared to the Mackenzie.

A We have a classification of major and minor river crossings that actually relates to the manner in which they are built. Usually a major river crossing is one that is handled by a separate contractor; a minor river crossing is one that is handled by the contractor dealing with that particular spread.

Q Well, that's where my trouble has come, this definition "minor" and "major" is a contractual definition.

A It's a piece of jargon that we use in the context that I just described, yes.

Q But it would be agreed that this problem is a potential problem for all the rivers that exit on the North Shore, including the Malcolm and the Firth.

A When we say "minor" in the context that I've just described, we don't mean insignificant. They are very significant rivers.

Q Dr. Cooper, would you agree that the appearance of icings in a stream channel downstream of a proposed pipeline crossing tends to indicate that there could be a ground water flow in

the stream at the crossing?

WITNESS COOPER: Either a ground water flow in the stream at the crossing, or the presence of some springs in the banks or in the valley, so to speak, downstream of the crossing, either one of those causes could be responsible.

Q And that in fact there are a significant number of icings downstream of the proposed pipeline crossings, both along the Yukon coast and in the vicinity -- in the valley of Norman Wells.

A I couldn't give a firm answer on that, in that most of our work on identifying icings has been concentrated on the interior route in the Canning River. There has been work on-going this winter that will give more definite answers to it.

WITNESS CLARK: I can answer that, the answer is , yes.

Q Both with respect to the Yukon coast and Norman Wells?

A Yes.

Q And that in all these streams, fish tend to over-winter in the patches of open water that are associated with or adjacent to the icings.

A I can't give a definite answer to that, but our fish biologist has identified for us the areas now where they suspect over-wintering

fish.

Q Yes, but Dr. Clark --

A It certainly is not all.

Q -- no, but wouldn't you agree that your fish biologist has indicated to you that the patches of open water associated with these icings are a natural place for fish, and I think particularly char, to over-winter?

A Yes.

Q It doesn't mean that every patch of water is going to have over-wintering fish, but I take it that every patch is a potential over-wintering place for fish.

A I think that's correct.

WITNESS HOLLINGSHEAD: I think I might add, Mr. Scott, that there are not patches of open water associated with every icing, as you suggest.

Q No, I didn't mean to suggest that, but what I'm trying to -- the point I'm trying to make is that where those patches of water occur in the winter, they are frequently associated with icings.

WITNESS CLARK: A I would think that there would have to be a repeated occurrence. If for instance there was open water in a location this year and it was frozen to the bottom next year, and so on, that it's likely that the fish would adapt naturally to

that particular environment and not select that particular area that might be open this year.

Q So what are you telling me, on the basis of your understanding that the fish to that extent are a creature of habit, they go to the open water areas they've gone to before?

A I would think that would be the case, yes.

WITNESS HOLLINGSHEAD: If I might add just a word, Mr. Scott. The potential over- - fish over-wintering areas which have been suggested by the fish biologist are primarily associated with the warmer water springs and there are comparatively few of these potential areas. They are certainly not associated with all of the minor stream crossings along the --

Q Well, the fewer there are, I take it, we can say the more important they are.

WITNESS CLARK: I don't think we're qualified to answer that, Mr. Scott.

Q Well now, Dr. Clark, if the pipeline were at a crossing to intercept this ground water flow, I take it that there would be presumably no icing at the customary place unless a solution for the problem were found.

A Do I understand you to mean that we wouldn't put the pipeline where an icing naturally occurs?

Q No, I am suggesting that if the pipeline in the type of diagram I've described intercepted the ground water flow, there would be no icing at the customary place, and in considering that, I ask you to leave aside your solution to which I will come.

A If the pipeline did intercept the aquifer that was producing the open water, unless the open water was associated with a very deep source of water, that would be unaffected.

Q In that situation, if the bulb had that effect, I take it that there would be no icing at the customary place?

A That's a good possibility, yes.

Q And if that customary place were a place for fish, there would be either no fish or they would be trapped and die?

A If the icing depleted their water, that's correct.

Although I should say that we have found open water in the lower reaches of rivers where there is substantial icing upstream from it.

Q Now, Dr. Cooper in his overview evidence, Dr. Church showed us a photograph of an icing that developed below the river bed and lifted it up by several feet. Have you seen that photograph?

WITNESS COOPER:

A No sir.

Q I would like to show you Exhibit number -- photo number 76R, page 33 of the exhibit which was put in earlier in the week whichis Mr. Church's photographs. I don't have the exact exhibit number, Mr. Commissioner, and ask you to look at the second photograph.

A Yes, sir.

Q And that appears to be, I take it, what Dr. Church has described?

A Yes, sir.

Q In fact, I think we have Dr. Church in the picture, don't we?

A Yes, sir.

Q Now, in the Battell report, and as I understand the applicant's reply to Question 38, it is stated that the pipeline might cause extensive ices, icings where it crosses frozen rivers with significant ground water flow below. And you agree with that?

A Well yes, under the conditions that we've discussed in the past 20 minutes.

Q Yes. Well now, is it not possible that such deep icings might endanger the line, the pipeline?

WITNESS CLARK:

A I think that that is clearly an effective stress problem as we've described it, and what Dr. Church has shown there as I see it from a very brief glance, is where a layer of frozen soil has had water under pressure and it has lifted it

under that pressure. A comparable situation might be if a water main breaks near your house and your basement floor lifts and cracks, the house doesn't lift and crack.

Q No, but I agree with your analysis of what Dr. Church has described, but isn't it conceivable that that could be a danger to the integrity of the pipe, or expose it to pressure?

A The amount of force that that water can generate is limited by the overburden pressure. In other words, using my analogy, that's why the floor breaks and why the house doesn't lift, so it's not axiomatic that it would do damage to the pipeline, because that situation develops.

Q Well, why can't it exert that pressure on the pipe and do damage to the pipe?

A It's -- here we are dealing with a thin layer of frozen soil where with the pipe you're dealing with, as you've shown, a very substantial rigid element with a mass of frozen soil above it, and if that mass of frozen soil were not above the pipe, we wouldn't be cutting off the water.

Q Well, is it your position that the soil is going to give way before the pipe does?

A Oh, the crust would give way before the pipe.

Q Yes. Well what studies have you done in connection with this problem?

A Well the studies per se -- it's more by way of devising a solution for deeper burial in these crossings, for example. It's analysis of situations that indicate that that problem just wouldn't exist.

Q What I'm getting at is is there in fact any report, study or analysis to which we can have access, that catalogues any work that you have done in relation to this particular problem?

A No, there's not a report now, but there is a study that is underway. It has been for some time and it will be continued even through the summer, and ultimately we will have a report on it.

Q I may be here in September, Dr. Clark, so if you have it, I'd be grateful to have that, because there appears to be no other study of which we're aware that deals with the problem. Would that be correct?

A Well, our objective here has been to expose to you and your advisors as quickly as possible any time we have a study for you to see and we certainly would do the same then.

Q Well now, Dr. Cooper, I want to refer back again to Mr. Nuttall's report and his use, as explained by you, of the word "damaging", and I want to do so by referring to the Environmental Protection Board report which I think Mr. Commissioner is already an exhibit, On page 9 of that report, in Volume IV, there is a description of how large

icings have been observed to explode, and the authors say this, and I quote from page 9, column 1:

> "Occasionally the water pressures that create icing mounds are large enough to cause the mounds to explode, nearby structures and activities may be threatened. The most dramatic instance of such an explosion was recorded in March, 1928 on the Onan River in Siberia where a block of ice, 62 feet long, 16 feet wide and five and a half feet thick was carried along the river icing surface about 400 feet downstream shearing away a smallbridge".

And then a citation of the report is given. Are you familiar with that observation that is set out in the Environmental Protection Board's report?

WITNESS COOPER: A I'm familiar with some documentation on this, and in various discussions I've had, we've never really been able to confirm the meaning of explode in these descriptions. When we look at the pressures that are possible, we find it very difficult to believe that an explosion per se could happen, that it would be more due to expansion forces, et cetera.

Q Well, are you familiar with the recorded instance which is referred to in the Environmental Protection Board's report?

A No I'm not sir, no.

Q I take it, giving a more

general meaning to the term "explode", you would agree that pressures can be created so that the ice is transported at some distances under great force?

A Well, no, what I'd agree on is that pressures can build up naturally beneath the icing to an extent that it will force water to the top of the ice, and of course that's the mechanism by which they develop, by flooding over top.

Q Well, in that particular recorded case, a block of ice was carried some distance, obviously under some pressure, because it sheared away a bridge. Is it not conceivable that without solution, that kind of thing may occur when these pressures exist?

WITNESS MORGENSTERN:

A May I comment here, Mr. Scott? There are two aspects of the problem; one is the pressure associated with the venting of water from its confinement and the other is the magnitude of water that will then issue.

Our understanding of the mechanics of confinement associated with icing development is that the water pressure cannot exceed the weight of soil over it, since this is a few feet, perhaps five, six, eight feet, the magnitude of the water pressure from consideration just of equilibrium, can't be any greater than that.

When it tries to become greater than that, and -- it then lifts the bed and begins to vent.

Now, when it does vent, if there is a substantial amount of water contained in the aquifer, a lot of water can then come out and can transport things, but the association of a transport with high pressure doesn't follow.

Q Well, I take it that the transportation is achieved by the high pressure?

A No, it's achieved by the discharge of water out of the venting.

Q Well then, what --

A -- the high pressure --

Q Well, what moves the ice?

A It's the flow of water moving blocks of ice.

Q all right. So that I take it it's conceivable that the kind of thing that was observed in this report can happen, the water under pressure is released in quantity and carries ice with it in such a way that damage can be done to whatever it runs into?

MR. GENEST: That question, I take it Mr. Scott, would assume that an observation made in Siberia in 1928 can be relied upon as accurate?

MR. SCOTT: Well it's reported -- is my friend suggesting it's not?

MR. GENEST: Well I --

MR. SCOTT: It's reported by a professional. I'm prepared to accept that.

MR. GENEST: I'm not.

MR. SCOTT: Well, the question I was asking Dr. Morgenstern has eluded me, but I take it to be this, that if the pressure exists, the water is released, is that correct?

A Yes.

Q And the water, because it is released under pressure, may move with some speed?

A A large discharge can come out and it can then move down the surface.

Q With some speed, presumably?

A Depending on the slope, it's a function of local conditions.

Q Yes, yes.

A In steep ground it would move faster, and gentle ground it would move more slowly. And also it's a function of the confinement of the channel, a variety of things like that.

Q The force with which it's released, that is I suppose the pressure under which it is held until it is released, will that effect the rate at which the water moves upon exit from the pressure source?

A It would be more controlled by the nature of the uplifting and breaking of the ground, rather than the actual source pressure. The point the maximum pressure could get to before it begins to bend would be limited by the weight of material above it.

Q And I take it that that water can carry a large piece of ice in appropriate cases.

A It's certainly moving water can transport things, and then how large now becomes a function of how much water and channel configuration and so forth.

Q Are Dr. Morgenstern or Dr. Cooper or Dr. Hollingshead or any of you familiar with that paper reported in 1960 by Checko Teoh? I don't know the precise reference but it's contained in detail in the Environmental Protection Board's Report.

WITNESS HOLLINGSHEAD: No sir,

WITNESS COOPER: No sir, I'm not.

Q Would an examination of that paper

potentially lead to any qualification of your views? No, what concerns me is that all of you have given direct answers to my questions, for which I'm grateful, as I understand it none of you are familiar with the single reported incidence. Would it help to look at that report?

WITNESS COOPER: Well, we could certainly better comment if we could study it in some detail.

WITNESS HARDY: What is the reference again?

Q Well, it will be in the back of the Environmental Protection Board's Report. I don't have the details, it's a 1960 report.

Now, Dr. Clark, on page 19 of the canned evidence, again dealing with your responses to the Assessment Group's Report, you were dealing with the principle of convection, which if I remember correctly, is the principle by which heat is transmitted through flowing water in these circumstances.

WITNESS CLARK: That is correct.

Q And at page 19 on the last paragraph of the page you say, and I quote:

"In general the effects of convection on the development of the frost bulb around a chilled pipeline are twofold: Firstly convection tends to reduce the size of the frost bulb."

And I think that was the evidence that you gave.

A Yes.

Q And I take it the theory is that the water , the ground water in our diagram moving through the March diagram carries heat to the frost bulb and in your words "tends to reduce the size of the frost bulb."

A That's correct, yes.

Q Well now, in the Battell Report in their summary on the last page they say:

> "In general the results indicate that moderate sub-surface flow can have a significant effect on the size and distribution of the freeze zone around a chilled pipe. In local regions where permafrost is not present but where weather conditions cause several feet of soil surface freezing, a chilled pipeline may drive the local frost zone to a depth several times that of the undisturbed freeze depth."

And then this remark:

> "Moderate convection only delays somewhat this penetration."

Do you agree with that observation?

WITNESS SLUSARCHUK: It does delay the penetration. I think they are talking about -- I think they are referring to a case where there was a limited depth of soil in the geothermal program that they were actually referring to. A more reasonable -- so from that sense I think in the context that they're probably talking about there I wouldn't

disagree with it, but in general I would disagree with it, yes.

Q You disagree with that paragraph of the Battell Report in general.

A That point.

MR. GENEST : Thats not what he said.

MR. SCOTT : I'm sorry, what did he say? I'm not quite clear.

A I would disagree -- let me put it this way, in general if you've got convection, the equilibrium position that the frost bulb would tend to go towards in the convection case would be at a -- would be smaller than a case where convection was not considered. So in that sense it's not only ~~delaying~~ it, it's actually retarding it.

Q Well, --

A Stopping it, in fact.

Q Well, Battell says that moderate convection delays the frost penetration.

A It does that.

Q Yes, all right. I take it that they have nowhere suggested that it reduces the size of an existing frost bulb.

A No, I don't think that's correct at all, sir. You have our answer 38 there, and I'd like to refer you to 38-1, that the whole situation is really shown right on that figure exactly what we're talking about.

Q No, but what I'm asking you is that apart from theory, you have the Battell

Report which doesn't suggest that it reduces the size of the frost bulb --

A It does suggest it. Just in that particular sense that you're saying there it doesn't, but in other places it does suggest it, and that's how we got our information. I think it more than suggested it, it actually says it.

Q Well, perhaps by Monday you can produce the portion of the Battell Report --

A Yes sir.

Q -- at which that point is made. Now, Dr. Cooper, would you agree that even though icings may generally form as has been said in the same location each year, that their extent is highly variable from year to year?

WITNESS COOPER: In some cases it is; in some cases it's, I believe, less variable.

Q I take it that you have some data, that Blench has some data on the size of icings.

A We did a reconnaissance that you were quoting earlier, that gave some rough data on that subject for one season, yes.

Q And is that the limit at the present time of your reported knowledge?

A Of our reported knowledge, as I mentioned earlier, there are ongoing studies.

Q Now again in question 38 of the Assessment Group Report, you agree that the frost bulb under rivers could lead to the formation of icings. We haven't been able to find a report on the size of these icings. Is there one as far as you know?

A No sir.

Q Well now I've been referred, Dr. Cooper, to the National Research Council workshop seminar on permafrost hydrology of 1974, and there is there a paper by Van Everdingin -- have I pronounced that right?

A I'm not sure, I'm not aware of it.

Q Which mentions east core mounds or open system pingos, and the author of that paper says:

"A last phenomena,"

and I'm quoting,

"A last phenemena to be mentioned in connection with ground water discharge is the ice core mounds known as open system pingos about 500 of which have been mapped by Hughes, 1969, in the Yukon. They are mainly confined to narrow valleys outside the limits of Wisconsin on Glaciation where permafrost is continuous but relatively thin, and where a small but continuous supply of ground water is available."

Are you familiar with that phenomena?

A No sir. Is it associated

with river bed icings, or is this a ground ice?

Q It isn't clear from the answer. It's created, as the author says, by ground water discharge.

A Yes.

WITNESS HARDY: I think, Mr. Scott, that there are members of the panel that are quite familiar with pingos.

Q Well, I understand that, Dr. Hardy, but I think we're talking about a different kind of pingo now.

WITNESS CLARK: We are talking about a ground system pingo now.

Q Well, the author goes on, Dr. Cooper, to say:

"Gradual growth of ice lenses by freezing of seasonally or continually supplied ground water is likely responsible for the formation of these dome-like structures."

Does that help you?

WITNESS COOPER: Well, if you could indicate where this is a river bed associated feature, or is it a ground icing that is associated with a spring?

Q Let me read the rest of it.

A Okay.

Q "This particular possibility may warrant their further study in the light of potential influence of chilled gas pipelines on the movement of sub-surface waters".

Now, are you familiar (a) with that phenomena?

A No, sir, I'm not.

Q And I take it that you have no reports or studies connected with what this author at least describes as open system pingos caused in the way he's described?

A No, sir, I do not.

Q No.

WITNESS CLARK:

A The studies that I've described on icings that are being carried out by our hydrologist would include open system pingos, in fact he's in close contact with Van Everdingin and other researchers in this field, and perhaps if you're looking to establish if there is any controversy I could say no.

Q Controversy with whom?

A Are we in agreement with that, I would say by and large we are in agreement, and --

Q Yes. Well what do you understand the author to mean then by an open system

pingo?

A I understand it to mean a ground icing phenomena.

Q I take it if the author were to refer to something other than a ground icing, you would not be able to comment on his observation?

A I believe he also comments on river icings.

Q Well do I understand that -- let me ask it more directly. What do you understand this problem refers to?

A Drainage on slopes.

Q And you don't see anything particular about this problem that is not directly dealt with in the icing question?

A The drainage on slopes involves more than icings, yes.

Q Isn't it conceivable that these pingos could form on the interior route near your pipeline?

A It's conceivable that they could form near our pipeline, yes.

Q Well has any observation or any report been made about the potential effect of the -- of pingos like the 500 which have been mapped?

A Relative to the pipeline, you're talking about?

Q Or to environmental concerns?

A Yes, we have discussed the implication of pingos on the pipeline, and I've heard discussions with others, with Dr. MacKay, and we don't view pingos as being a problem.

Q Well, the author of this report flags the desirability of further study in connection with chilled gas pipeline installation , and what I'm asking is, has that study been done as far as you know, and can you refer us to it?

WITNESS MORGENSTERN:

A As I understand his concern, he draws attention to the development of ground ice features, the open system pingo, when you have flow on slopes being impeded by freezing fronts, and this is the situation that the pipeline creates for example along the Norman range, and that the phenomenum of an open system pingo leads him to the concern for developing icing features in ground water flow systems.

In this regard, Dr. Clark's people have carried out studies, are carrying out studies where ground water emissions occur and where the mechanics of open system pingo growth might be generated by the pipeline, and are putting together studies of drainage and so on that would reduce this problem.

Q Yes. Well are any of those studies available to us, or is it again a problem of their being underway and not at hand?

WITNESS CLARK:

A It's part of the overall study that I've described.

Q No, but I take it that the answer to the question indicates that there is some study underway?

A Absolutely, yes.

Q Is that correct?

A That's correct.

Q Yes. I take it that there is no study presently available?

A There is no report presently available.

Q Well now, Dr. Clark, the solution proposed for this ground water problem and its various manifestations is, as you have said, at page 2729 of the transcript, installation of a culvert insulated across the frost bulb. Is that in essence, correct?

A That's correct.

Q Now, I take it that this is a -- not to criticize it as a matter of principle, that this is a novel and unusual design, never before done under these circumstances?

A I guess I could be accused of saying that I'm giving a further glimpse of the obvious if I say that we haven't put in chilled pipelines under any rivers in the north.

Q And you're aware of no case in which this solution has, in fact, been tested

on the ground?

A Well, the solution of carrying water through frozen ground has been tested in many cases, has been used practically in many cases for years and years.

Q Well, have you any reports or studies that show, or any geothermal work available to us, that show that these culverts will do the job in the context in which they are presented here?

A There are a number of reports available in the literature on insulated pipes in frozen ground. I could provide you with some references on that.

Q Well, I would be grateful -- I would be grateful, not particularly for works on insulated culverts in frozen ground, but I'm interested in insulated culvert work that may have been done or papers that may have been written that relate to the solution that is proposed for this particular problem. Is there anything of that type?

A No, I don't believe that the elements that go into this solution, there are papers relating to each of the elements.

Q Well, let me ask you some questions that occur to me. How are you going to select the proper culvert size?

A That would be selected on the basis of what quantity of water it was necessary to carry, at what velocity it was necessary to carry, and so on. Selections of culvert size I think

is a fairly straightforward thing.

Q How are you going to find out those things?

A This would be, I believe, revealed by the types of studies that we are doing. Final design detail predicts that.

Q Well, do I understand then that you are presently doing studies that will reveal that matter, will reveal that information with respect to every crossing on the Yukon slope?

A We understand, first of all, permeability. We have information on where icings occur naturally. We have information on where fish over winter, the types of studies that we are doing are to locate this as precisely as possible the aquifers during winter and summer field work programs.

We -I think, have identified all the elements necessary to go into the solution, and it's simply a matter of carrying on.

Q Well, wouldn't you agree that different sizes of culvert are going to be required, depending on the site situation?

A Not necessarily, it's a matter of size and frequency, different spacing of the same size might be used. That could be the more common feature.

Q Well when you say might be used, what do you mean?

A Well,/if it's a very small area, then a very small amount of water would use one

culvert. We might use them every 10 feet in other places, the same size.

Q Well is it intended that the construction superintendent, when he comes to the river, should decide this question?

A Absolutely not.

Q And therefore I take it that the dimensions of all these problems are going to be mapped and those determinations made well in advance?

A That's certainly our intent.

Q Yes. Now, how will the culvert be placed in relation to the pipeline?

A Above it.

Q In every case?.

A At this point in time, that's what we conceive but I couldn't say for sure until we got the final design detail.

Q Is the culvert going to have any granular material in it?

A That's again a final design detail I wouldn't anticipate that it would.

Q You wouldn't anticipate that it would?

A Not at this point.

Q How are you going to handle the culvert inlet and outlet? Aren't those the key areas?

A Yes.

Q How are you going to handle that?

A In a conventional manner.

Q Well, what's the conventional manner? I'm not party to these conventions.

A Perforated pipes, for instance.

THE COMMISSIONER: I'm sorry, what did you say?

A Perforated pipes with holes in. The handling of ground water in drainage systems and so on use all these techniques?

MR. SCOTT:

Q That's an extension of the pipe, is it not, with a lot of holes into which the water will seep or flow?

A Yes.

Q The same thing at the outlet?

A That would be a final detail that we would look at, I couldn't give that information for sure now.

Q Well, I agree that it may be a final detail, but it's crucial, isn't it, because if those two details aren't fully understood and worked out, the drainage system won't operate, will it?

A If we get water in, we have to get it out.

Q Yes, and you have to get

it out?

A Yes, indeed.

THE COMMISSIONER: When you say inlet and outlet, do you mean an inlet and outlet above the surface of the ground or --

A No, no, it would be entirely below the bed of the river.

Q Well inlet and outlet refer to the sections of the culvert on either side of the frost bulb?

A Yes. Perhaps sir, if I could -- I know you're going to refer to your drawing. I've got another one -- can I take advantage of the same process here and put one up that will show what I'm talking about?

The inlet and outlet is, of course, conceptionalized here, it shows the concept -- the upper diagram there shows a situation where you have a very deep gravel bed with a substantial flow. We have shown the distortion of the frost bulb that would occur, in that case where the frost bulb wouldn't cut off the river we wouldn't put in a pipe, the water would flow around it. In the case of very shallow gravel bed where we would cut off the water, then you can see we've extended, which I reluctantly refer to as the Templeton Wall, but we've extended it down into the impermeable layer below and have carried the water through the upper part of the frost bulb. Again its relation to the pipe there throughout is purely conceptual.

Q Well, Dr. Clark, in both those examples there is no frost penetration below the river bed, is there?

A The bottom of the blue, you would be quite free to assume that that's into the river bed.

Q Well, what concerns me is that is there in every case going to be room for the pipe if the frost penetration comes down to there, you are not going to have much space unless it runs right through the gas pipe itself.

A We would go down deeper in that circumstance.

Q Bury deeper?

A Oh yes, the depth of

burial will be dependent upon the natural frost penetration, and of course as the frost goes naturally through the bed itself, then we're not cutting off anything. You'll agree with me there.

Q No, I didn't understand your observation.

A If the blue extended right down to that impermeable barrier with no pipeline, then we're not dealing with a problem.

THE COMMISSIONER: Then you haven't changed anything?

A We haven't changed anything there, no.

MR. SCOTT: Well now, I think it's obvious, isn't it, that this resolution of the problem calls for a great -- a large variety of responses that can only be determined on the site.

A I don't believe that's obvious at all.

WITNESS HARDY: I think, Mr. Scott, to put this in its proper context, there is nothing new on this project as far as putting in culverts as an installation is concerned. Every time you build a railroad or a highway, you see, you have the same problem, and there are books such as you have by the same author, Charlie Neal, you see, that deal with culverts, culver t design. What is different on this project are some of these special freezing effects so that the problem here becomes simply a

detail that is added to the conventional design of culvert systems on a project such as this, or a railroad or a highway.

WITNESS CLARK: I didn't mean also to eliminate entirely the necessity for good sense and good judgment during construction.

Q What is the anticipated life of the culvert pipe?

A Life of the pipeline.

Q It better be, hadn't it.

A I'm sure they will both have a long and healthy life.

Q If something should happen and it gets blocked up, what are you going to do?

A Well, the first thing we'd do is we would have an indication that it's blocked up, and it would be replaced.

WITNESS HARDY: That is a standard maintenance problem, of course, blockage of the culverts.

THE COMMISSIONER: May I ask a question? The drawing, Dr. Clark, shows the culvert passing through the frost bulb, and the pipeline, that white dot, is four feet in diameter. Was that supposed to be the scale, does it mean the culvert would be the same size as the pipeline?

WITNESS CLARK: No, no sir. That is just conceptual. The culvert could be six inches to 18 inches in size, I would think.

MR. SCOTT: Both Dr. Clark and I have chosen our own scales in presenting our drawings.

THE COMMISSIONER: Well, his is colored.

MR. SCOTT: The red of the bulb looks ominously like the red that is associated with the maple leaf route. I think the drawings will be used by either applicant in due course, except the maple leaf won't require this particular problem to be solved.

WITNESS CLARK: The colors were chosen by geologists. They have a special feeling for color.

MR. SCOTT: They are not remote from politics either, that's my observation.

MR. GENEST: The frost bulb will be maple leaf shaped.

MR. SCOTT: Well, are there any detailed criteria established for deciding at which stream crossings you're going to put these culverts?

A No, there would be a number of elements to go into that. Our first consideration has to be how it would affect the environment, because we don't see it as really affecting the integrity of the pipeline.

Q Well, to use a phrase

that is common, is there any methodology devised for establishing these criteria?

A I would say yes, we have, I think, a well-conceived program that will establish the criteria.

Q Are there any details of it available for us?

A No, what I could -- we have for instance a study of the geophysical applications to the pipeline in its entirety under way, and a report on that will be prepared if we're on schedule within a few weeks. The intent there is to outline the methods that would be used in these situations to further define the areas from a physical point of view. The fish biologists, of course, are inputting their information on that aspect of the environment. The river engineers input their information on the potential impact of icings, for instance, on shifting flow for lateral scour. So all of these put together, I think, will establish a rational method of design.

Q Well, I take it that the pipe that runs across, the drainage pipe is going to be installed at the same time as the pipeline.

A No, it will follow the pipeline.

Q Well, how long will it follow the pipeline?

A After the pipeline is in place.

Q No, but is it going to be put in the same --

A The same construction period. It's my intent now, would be that it would be put in during the same construction season but I don't believe it would be essential, it has to be put in before the line goes into operation. It may prove the logistics of things may prove that it's better to put it in the following season. I couldn't speculate on that.

Q It clearly has to be put in, in every case, if it's to be remedial, before the pipe is chilled.

A That's right.

Q Yes, because if it isn't you won't have any fish in the classic case where it's required.

A I think that's not a correct observation.

THE COMMISSIONER: May I stop you both for a minute? You were talking about a culvert a minute ago. Now you're talking about a drainage pipe.

MR. SCOTT: Well, I've used drainage pipe; I think culvert is the word Dr. Clark has used.

THE COMMISSIONER: You're still on the same thing?

WITNESS CLARK: Yes sir.

MR. SCOTT: Well, let's take this example where the pipe is installed and chilled in a river bed and it is decided for some reason not to put the culvert or drainage pipe in till the following year after chilling. How are you in a position to guarantee that the fish that winter in those pools won't be killed?

A Well, we would never gamble on that. There are two, if you like, theories, as to where the water that keeps the over-wintering area open comes from. One is that it comes from very deep springs. Our own feeling is, and our planning now is that it comes in shallow aquifers. We have made a conservative assumption, that assumption being that we will affect the fish and therefore we will put these in at the time of the construction. In fact, all of our drainage and erosion control methods, the cost benefit of putting it in when you're there so far exceeds coming back and doing it later that we wouldn't gamble.

Q The environmental benefits may be identical in that case.

A I think in many cases they go hand in hand.

Q In any event, that is your expressed intention?

A Yes sir.

Q Dr. Cooper, is the pipeline going to cross any areas where there are natural

icings or will be natural icings at the time of construction?

WITNESS COOPER: Yes, there could be some natural icings at the time of construction.

Q Yes, and indeed I think on some of the maps, natural icings are shown at the point where the pipeline crosses.

A This may well be.

Q Just for the purposes of the record I refer to the maps in your water availability study of May, 1973. I won't trouble to put them in now. How is this problem going to be handled?

A From a construction viewpoint?

Q Well, how are you going to handle the drainage?

A Well, I'd have to ask Mr. Williams on that construction.

Q Here is the situation, the pipe is in the course of construction, and it is going through an existing natural icing. The icing is there, and the pipeline construction crew is coming to it. How is that problem going to be dealt with? As a draining problem and as a problem of maintaining the life of the fish who may water in adjacent pools.

WITNESS CLARK: But the line isn't being chilled, sir.

The icing would be identified well ahead of the operation.

Q No, but isn't the ditch going to fill with water as you dig the ditch across the natural icing, isn't it going to fill with water and drain the adjacent pools?

A Oh.

Q You'll get char for lunch, you'll just have to pick it up.

A There's no way that that pool could be supporting fish, if there wasn't water in there.

Q I understand --

A The ditch is not going to drain a pool. We're going down below this river, we have a low point there, with water all around. The ditch fills with water much the same as it does in downtown areas where we drill through water all the time.

Q Well, let's be realistic for a moment. Isn't it perfectly clear, Dr. Clark, that in that situation where you have to proceed through a natural icing, it may not be of great consequence but pools are going to be drained and fish may die. It may not be the end of the world, there may be other fish.

A I cannot conceive that happening.

Q No risk?

A No risk absolutely there.

Q And I take it that your general proposition is that there is no risk with respect to any of these -- with respect to this solution?

A I don't believe there's risk in the sense that you're using it.

Q Well now I would just like to ask Dr. cooper one or two questions if I could before the break, Mr. Commissioner, that arose out of his answers the other day.

Dr. Cooper, you said on Tuesday that the 100 year flood of the Mackenzie River could be determined adequately, based on 25 years of record?

WITNESS COOPER:

A I believe if my memory serves me right, 25 to 35 in my opinion. .

Q Yes, and I think you said that 35 to 50 years of data would be adequate for all other rivers on this project?

A They would be adequate if --

MR. GENEST: Have you got the transcript, Mr. Scott?

MR. SCOTT: Yes, I have, page 3068. Now you haven't got the transcript.

Volume 25, Mr. Commissioner, beginning at line 15, Question:

"Well, just so I understand for later purposes, is it your proposition that you can obtain a reliable estimate of

the 100 year flood after 25 years of observation on the Mackenzie Valley -- on the Mackenzie River?

A Yes, it's my opinion that 25 years on the Mackenzie River is adequate. On a lot of other rivers I'd say no to that.

Q What's required on other rivers that are within the ambit of this project?

A I would say 35 to 50."

A That's correct, and I meant that in reference to if we would use a 100 year flood that was based on historical records.

Q Yes. And would you agree that the true 100 year flood cannot be determined, and I mean the true 100 year flood can't be determined without an infinite number of years?

A That's correct.

Q Yes. And obviously one's estimate , one's approach or estimate towards the true 100 year flood becomes better the longer the record of observation goes on?

A That's correct, sir.

Q Yes, and that although you can never know, because we don't have infinity available, that your estimate is right, you do in fact compute the chances of being right?

A That can be done, sir.

Q Yes. Well now, you said that 25 years on the Mackenzie River is adequate. I want to get a little clearer what is contemplated by the word adequate, and would you agree with me that plus or minus 20 percent would be adequate?

A I haven't done the statistical analysis that would be required to -- for me to quote a figure like that.

Q Well -- are you able to quote any figure as to what adequate means in your answer? Is it 25, have I got it wrong? What is the --

A 25 what?

Q Plus or minus?

A There would be a plus or minus, there would be a plus or minus value associated with that, yes.

Q All right. Well now, can you give us your judgment, I understand you haven't thought about it, about what that figure would be. Is it 20, is it 25, what is it?

A Sir, I can't give you that judgment without doing the analysis.

Q Well then what did you mean by adequate?

A Well what I would -- what I meant by it is I believe with 25 years of record, we can predict a 100 year flood on the Mackenzie River, and of course we would design taking into account higher flows where necessary.

I do not -- like if the integrity of the pipeline was based on our 100 year estimate, I wouldn't accept that as being satisfactory, I would want to look at higher flows as well.

Q But in prediding this, you have said that 25 years' observation is adequate. Now, obviously you agree with me that it's not perfect?

A No, certainly it isn't perfect.

Q All right. Well, what is the margin of error that is acceptable to you in the determination of adequate?

A I'm having a little trouble getting your question, what you're driving at.

Q Well you're predicting, or in determining the 100 year flood, you're predicting the maximum flood that will occur in a period of time that you and I, unless we are unlucky we're not going to be around to observe?

A No sir, we're not doing that.

Q What are you doing?

A We are predicting an extreme flood event that we're using for purposes of preliminary design.

Q Well over the weekend, can you determine the margin of error that you contemplate when you say a 25 year observation is adequate?

A Certanly.

Q Thank you.

We can take a break now, Mr. Commissioner. I'm moving onto a new subject.

THE COMMISSIONER: Well this is a coffee break without coffee then.

MR. SCOTT: Oh well then,don't bother, I can go ahead.

THE COMMISSIONER: We will let you know as soon as it arrives.

MR. SCOTT:

Q Dr. Morgenstern, I want to turn to some questions that relate to unstable slopes. I gather first of all it would not be going too far to say that the issues inherent in the analysis of slope stability or instability, and this isn't intended to be pejorative, but is really an art that relies on very precise and thorough and calculated judgment?

WITNESS MORGENSTERN:

A It relies, certainly to some degree on experience.

Q Yes. And would you agree that with respect to slope stability problems in permafrost areas, the level of experience to which you've referred, is compared to other matters, relatively low?

A Yes. Well less.

Q Now, in your evidence at -- I don't know the volume number, but at page 2346,

-- it's Volume XX, Mr. Genest. 2346, you began by referring to a number of studies done by government, universities, industries and the applicant.

A Yes.

Q You observed that while these studies were not in anticipation coordinated, the result has been that they have been as we can see, complementary, and a whole view has developed?

A Yes.

Q Yes, and then you went on to say they, meaning the studies, I presume of the various types, have led to a clear understanding of where land slides occur in permafrost terrain, how to calculate the likelihood of their occurrence, and how to design stabilization measures to prevent or inhibit them, and it's the purpose of my presentation now to illustrate some of the findings that have brought us to this position of clear understanding?

A Yes.

Q Well now, I got the impression from that that the uncertainties have now been overcome in this area, is that correct?

A With regard to establishing safe acceptable designs, yes, that's my view.

Q Is there any realm of uncertainty left in respect of slope instability or its solutions?

A In terms of evaluating input data, there will always be uncertainty with regard to knowing precisely the soil properties, and

more specifically with regard to permafrost terrain, precisely the groond ice configuration.

Q Are there any other uncertainties in this discipline at all, or is everything else now decided?

A There's an element of uncertainty about the rate of advance of the thaw front.

Q I'm sorry?

A There's an element of uncertainty about the rate of advance of the thaw front.

Q Yes. So we have those three elements about which there is, as you put it, a range of uncertainty, in your ability to observe, I take it that's what you're talking about, is it?

A To know in detail.

Q To know in detail?

A Yes.

Q Are there any other uncertainties that exist in this art of combined experience and judgment?

A Well --

Q No?

A Perhaps, these are the most important ones.

Q Well, I would be grateful toknow if there are any others in your view,as one of the leading men in the field.

A These I think are the main

ones.

Q Yes. Are there any uncertainties left to us in the design or application of solutions? Both in the laboratory and on the ground?

A We can establish safe solutions.

Q No uncertainties inherent in that?

A Other than to the degree that we've already admitted that uncertainty exists in knowing ground conditions.

Q No other uncertainties apart from the ones you've referred to, therefore?

I mean this is my for once and for all opportunity to ask questions, I want to be sure I have them all.

A Yes, yes.

Q No others?

A None come to my mind at this time.

Q Well now, in a graph or chart that you made available, you demonstrated that not more than 2 to 3% of the pipeline route exhibits potential instability on the basis of conventional criteria. Do you remember that?

A On the basis of the criteria that we have adopted for establishing, selecting these slopes, yes.

Q Well now, I've worked that out --

A Conservative criteria, not conventional.

Q I've worked that out and it comes to roughly 25 miles of route exhibiting potential instability, would that sound about right?

A Yes.

Q Yes.

A Classified as.

Q And of the 686 slopes that have been catalogued, I think it's obvious, is it not, that a very substantial number of them are short slopes scattered along the route.

A Yes.

Q Yes, so that our 25 miles or whatever it is, breaks down into -- there are obviously some big ones, but a number of short slopes that are scattered at various places.

A Yes.

Q And I suggest to you

that your observations make it clear that many, if not most of those slopes, are or do occur on valley walls and river banks, and other like areas.

A Yes.

Q And you would agree with me that those are areas of substantial environmental concern, generally speaking.

A Yes.

Q Well now, when you were talking about slope stability and slope failures, I take it that you're talking about what I would normally call landslides and mudslides.

A Yes.

Q Yes, and these slides involve, I think as you told us, a range of materials that run all the way from soft clays to rocks. Hard rock.

A Yes, in the conventional sense. My presentation was addressed to landslides in permafrost, ground ice problems.

Q And that these failures just so I understand it, are gravity forces.

A Yes, except when exaggerated by earthquakes.

Q And I take it that what we have not been talking about in your exposition is erosion by running water.

A Yes.

Q And we've not been talking

about water-eroded gullies and that sort of thing.

A That's right.

Q Yes, now I take it from what you've said that you would agree, however, that in addition to the cases that you have discussed and analyzed, many slope instability problems owe their existence to a combined effect of water erosion and slope failure.

A Problems of transport of sediment owe their effect to a combination of these two, yes.

THE COMMISSIONER: Excuse me, problems of transport?

A Yes, I was rephrasing slope stability to me, a problem of slope stability to me is a problem involving gravity forces, the sheering of soils and so forth; whereas a problem of slope stability might be generally interpreted as one concerned with the movement of the sediment as well, here the erosion moving over a slope so that the transport of sediment might be due to the breakup of the ground, and then running water coming over the sliding mass. So that the slope problem might be a sediment transport problem as opposed to a mass sheering problem. Is that helpful?

Q I'm not -- forgive me, I'm not quite with you. I understand it when you say that the slope may sheer.

A Yes.

Q And the toe of the slope presumably certainly in open water, if you're talking about a river crossing, or a stream crossing, is likely to be transported downstream. Now I take it that you were talking about instability in slopes unconnected with river or stream crossings.

A Yes. Mr. Scott asked me "Are slope problems not due to a combination of both gravity forces and river erosion?"

And I changed the terminology to say that the problem that results from a combination of these things is the movement of sediment in the water course. Slope problem in my terms just is due to the gravity forces.

MR. SCOTT: Q But it's a matter of general observation that the kind of problems, gravity problems that you've been discussing and showing and exposing for us are frequently connected with water or frequently seen with water erosion problems.

A Yes.

Q And it wasn't your intention to deal with the -- in that exposition -- to deal with the water erosion case, if I can put it that way.

A That's right.

Q You were dealing with gravity problems.

A Yes.

MR. GENEST: May I interrupt, Mr. Commissioner? Just to clear my mind, is Mr. Scott talking about a bank erosion by a water course or is he talking about erosion down the right-of-way?

MR. SCOTT: As I read Dr. Morgenstern's evidence, I suppose it's a tribute to him to say that it's sufficiently clear to say that even I was able, with minimal assistance, to comprehend it. But I understood him to be saying that the forces that he was analyzing for us were gravity forces, and not water erosion forces. I have that correct, have I, Dr. Morgenstern?

WITNESS MORGENSTERN: Yes.

MR. GENEST: But water erosion by a water course, by a river, by a stream?

MR. SCOTT: Water erosion we will just have to leave it there, wherever it is occurring.

Q But I take it, to go back just one step, it is a matter of observation that water erosion is a problem that is found from time to time associated with the gravity slides that you were dealing with.

A Yes.

THE COMMISSIONER: Well, I think we're ready for coffee. We'll break for a few minutes.

(PROCEEDINGS ADJOURNED FOR FEW MINUTES)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT:

Q Dr. Morgenstern, I take it that as a matter of general observation, we can say that some slopes are unstable in their natural state, and some slopes may become unstable as a result of changes effected by man?

WITNESS MORGENSTERN:

A Yes.

Q Now, I would like to deal just for a moment with the prediction of slope failure, and I take it that the prediction of slope failure is the first place at which you must start in attempting to approach the kind of problems that confront you with the Mackenzie Valley pipeline?

A Yes.

Q Now, you referred and I only bring it up again with some temerity to C sub V and I don't want to get into it, but I take it that that is one of the critical factors in what is called the quantitative analysis of the hazard of one type of slope failure?

A It's an important parameter.

Q Yes. And it is therefore an important -- the quantitative analysis of which it is a part, is essential to determine the factor of safety?

A It's an important guide in

our total design of slopes, yes.

Q Yes. And that generally speaking in permafrost terrain, some kinds of potential failure can presently be predicted in quantitative terms? That is, by the application of formula?

A Yes.

Q Yes, and that on the other hand, there are other potential failures in permafrost terrain that can presently be only interpreted qualitatively?

A Yes.

Q And a qualitative interpretation is a description in words of the process, rather than a formula?

A Yes, though formulae may be used to assist our interpretation.

Q And would it be correct to say that the elements of these analyses that are peculiar to permafrost areas, have been developed only recently, that is in the last five years?

A The quantitative components the formulae.

Q Yes. I observe, for example, that in the literature attached to the canned evidence, with one or two exceptions, some of which don't deal with permafrost, the permafrost slope instability literature, I will say nothing about the authors, is really 1971-1974.

A Yes, to a large degree.

Q Yes. And I think you would

perhaps agree that as yet there has been relatively limited experience in applying than in the actual field situations?

A The prediction of instability has, perhaps I should say that only a few people have much experience.

Q And even those are, and I look at two of them, even those -- the literature relates to the last three or four years?

A Yes.

Q Yes. Well I agree, Dr. Hardy, that you don't have to write it down to know it, but it certainly proves it.

THE COMMISSIONER: There was a man here during the first week of the overview that made that claim. He was from Fort Norman, I think it was.

MR. SCOTT:

Q But as compared with other kinds of slope instability problems, I take it that there is no doubt that the experience in permafrost terrain is much more limited?

A It's more than -- I think one draws on the experience in other terrains as well, of course.

Q And would you also agree that the magnitude of some of the input parameters in actual field situations, has been relatively little known?

A No, the new -- there are

two novel aspects, that come first to mind, have to do with the evaluation of melting processes, and the identification of ground ice forms.

The evaluation of melting processes, the thermal aspects of this problem, we feel are well in hand. The evaluation of ground ice is something that we always wish we could do better.

Q I ask you though if the magnitude of some of the input parameters is little known, in field situations?

MR. GENEST: I don't understand that question, the magnitude of the parameters?

MR. SCOTT: Well, maybe Dr. Morgenstern would, and if he agrees, he can explain it.

A If we refer to say, the formulae that we use, C sub V and other soil parameters, we feel that we can evaluate them on a conservative basis. While we may not know them precisely, we know their bounds quite well.

Q Yes. I asked that question, and perhaps I, like Mr. Genest, I don't understand it in its entirety, and I refer to a paper of yours and Dr. McRoberts called the "Stability of Thawing Slopes" in the Canadian Geotechnical Journal for November, 1974, where at -- I want to file this as an exhibit -- where at page 465 you say,

"Little is known concerning the insight to magnitudes of these parameters and the role of cycles of freeze and thaw in affecting these parameters",

and I take it that there's no doubt about that?

A That is true.

Q Yes. You then go on, further down the page to say this, and I quote:

> "The shortage of well documented field case records of thaw induced instability is obvious, and research into the insitu properties of a fine slope,coupled with excess pore pressures will certainly be of great value".

A Yes.

Q Yes. Also in that paper at page 466, you are talking about bimodal flows which is one of the flows that you described with the assistance of diagrams and photographs , is that not correct?

A Yes.

Q And you are dealing with, and I think you told us that a bimodal flow, and it's dangerous for me to try to synthesize, had at least two movements, one out in the direction of the valley or in the direction of gravity, and one back which was called an ablation?

A Yes, in the headward directions, yes.

Q I'm sorry, I didn't --

A In a headward direction.

Q In a headward direction?

A An ablating back scarp.

Q In this paper at page 466, the second column, you begin in your words,

"To briefly consider the range of processes involved",

and I have to tell you that you were talking about bimodal flows.

A Yes.

Q And you say in the second paragraph on that page:

"A simple solution for the rate of ablation," and that's the movement back toward the head, is that correct?

A That's correct.

Q

"A simple solution for the rate of ablation has been presented which, in conjunction with observed oblation rates, yields a prediction of the heat flux available for melting. Although there are no reported measurements of the actual radiation impinging on ablaling scarp, it is encouraging to be able to model the failure mechanism."

I take it there's nothing disputatious in that paragraph?

A When it was written, that's correct.

Q Is there any doubt about it now?

A There are measurements.

Q Yes.

"It is unlikely that such a pro --"

oh, you may anticipate to what I'm going to refer.

"It is unlikely that such a process could be tolerated in the vicinity of any engineering work, and if a bi-model flow is initiated, it will have to be stabilized immediately,

possibly by covering with insulation."
Is there anything wrong about that?

A No.

Q No. Well now, let me deal if I can for a moment with preventative stabilization. I understand the analysis to which you referred in your evidence was designed to provide either by formula or by analysis of the process, a prediction of the hazards?

A Yes.

Q Now I take it that having identified or predicted a slope which is hazardous or unstable, the preferable course is to prevent failure rather than to allow the hazard to actually occur and then take cleanup measures?

A In all cases, except when the failure is induced by the maximum probable earthquake.

Q Could you expand on that exceptional category for me?

A Where shallow failure -- this is not failure of the pipe, it's failure along the right-of-way -- can be shown to occur when the very, very large accelerations that we adopt for our maximum probable earthquake are used in the analysis, it's my view that we should accept these shallow failures and treat them as a remedial work. The alternative would be to employ these verv conservative criteria at the outset and set about implementing the remedial works. This would, in itself, induce

environmental change and of course add to cost, and we would be exchanging reality which would be these sandwiches, berms and various things, which would be an intrusion, for a statistical improbability. So in that exceptional case, my view is to accept the damage which in any case would be a small increment of the damage that nature would be doing in that area; accept the damage under that high loading situation and fix it up afterwards.

Q So that in that case you've dealt with, what you really do is monitor and if necessary take remedial measures?

A We'd go in and fix up the right-of-way elsewhere.

Q But I take it that -- I'm sorry?

A If, for the normal case, the conventional operating case, your statement earlier that we would evaluate and stop instability, I would say that is correct, yes.

Q And I take it that in terms of stopping instability -- well let me put it this way, the options for prevention when you have predicted a hazard are (1) to re-locate or (2) to alter the slope in such a way that its stability is increased?

A Yes, there are a variety of schemes listed in the documents.

Q Well now, you have set

out in answer to the Assessment Group's concern -- or the applicant has -- a number of stabilization methods?

A Yes.

Q And you have given evidence about a number of stabilization methods. I take it from what you said in your evidence, speaking generally, it's apparent that there are a variety of slope stabilization techniques that have been devised and that have been tried and work in non-permafrost terrain?

A Yes.

Q And the history, or the experience of that is as these things go, substantial?

A Yes.

Q And that coming to permafrost problems for the moment, I take it that it's your view that some of those non-permafrost techniques can be utilized in permafrost territory?

A Yes.

Q But I take it that it's also from your view, reading your evidence, that modified or new procedures may have to be identified or have been identified to deal with other kinds of permafrost problems?

A Yes.

Q And would it be correct to say as a general principle, that the actual construction procedures for many of the latter case

of that stabilization methods, remains to be worked out and there has yet been little experience in applying them to the kinds of situations that may exist on this line?

A There is experience with -- if not all of them, a wide variety of them -- that we can draw from the practice in Alaska, where slopes have been stabilized. Also, part of our activity is to interpret what nature does. Nature has stabilized a large number of slopes, and in fact, if you translate some of the principles behind the configurations that we adopt, you'll see that we're learning from nature as well, so that we draw on these experiences. Also there are experiences along the Dempster Highway.

Q I wasn't really referring to the validity, which I accept at this point, in the questioning of the quantitative or qualitative analysis of instability; but I was suggesting and perhaps apart from, we can accept Alaska and the Dempster Highway, that the actual construction techniques have been relatively little tested insofar as modification of techniques for permafrost terrain are concerned.

A The configurations that I have in mind employ well known construction techniques. If the question asks, have we established test sites in the sense that Sans Sault is a test site, for pipelining, have we established test sites to demonstrate specifically within the context of this

project that various stabilization schemes work, no, that hasn't been done.

Q I can see that many of the techniques have been used across the world in non-permafrost terrain.

A Yes.

Q And you have said that some of those will be applicable as is to permafrost situations?

A Yes.

Q And obviously in those cases there may be some experience. You've also indicated, I think, that modifications and in some cases new techniques are required to deal with permafrost situations and you've told us that you and your associates and those working in the field have devised those techniques?

A Yes. Perhaps the problem is your use of construction techniques as opposed to design concepts. Some of the design concepts are new, but they employ fairly conventional construction techniques.

Q But I put it to you that apart from Alaska -- let me put it this way, that on the drawing board the design technique may be new or modified. The construction technique selected may be traditional.

A Yes.

Q But I put it to you that

the combination of the two actually being done is apart from Alaska and the Dempster Highway, at the present stage, a matter that is little known.

A Less known than non-permafrost configurations.

Q I wonder, we have the slide here which represents one of the techniques that you suggested, the sandwich technique.

A M'hmm.

Q Could you ask Mr. Williams -- Dr. Morgenstern, is this -- I take it that the technique shown on that slide is a traditional technique in terms of design?

WITNESS MORGENSTERN:

A No, well the illustration here illustrates several aspects of a sandwich that in various components can be used to stabilize this type of thawing slope. It might consist of just insulation, it might consist of drainage and insulation, or a combination of drainage insulation and surcharging.

The analysis to support the application of this is novel, in that it draws on the work of the last few years that you alluded to earlier.

Q Yes. Are you familiar with any case where that technique has been used in permafrost terrain?

A Nature has certainly produced insulations that have stabilized flat slopes.

Q Nature is a better workman than all of us.

A Yes it is.

Q In some cases. What I'm concerned about is leaving nature aside for the moment,

because nature created the problem we have to deal with, has that technique -- are you familiar with any case inwhich that technique has been utilized in permafrost areas?

A The rationale and understanding of this technique is novel. It has not been implemented explicitly in practice, or if it has, it hasn't been understood the way that we understand it.

Q Well now, just because we have it there, you called it in your evidence a sandwich, it's really sort of a Dagwood sandwich, isn't it? It's more than a -- it has a variety of layers, doesn't it?

A It has a variety of layers, yes.

Q Would you describe them for us?

A Yes. The components of the layers would be a drainage layer, or an insulation layer, or a surcharge layer which is the gravel. The peat might or might not be present, depending upon whether it slid off or if that's part of the natural configuration.

Q Could I ask one or two questions just so I'll understand the diagram? Over what length of terrain might that be an appropriate solution?

A This would be a solution that we think would be used to stabilize thaw

induced over any length, where this type of mechanism would exist, where planar slides are developing likely along the right-of-way and in glacial lake basin soils.

Q So it might be used in areas that in length were anything from 100 yards to 5 or 600 or more?

A Well, I doubt whether it would be as long as that,but in the order of several hundred yards.

Q Yes. Well now, beginning at the bottom, what is the first band, or is that the --

A This is the naturally thawed soil/which from the ground surface down is evaluated as unstable.

Q I see.

A Then the artificial device, so to speak, or the preventative measure, the stabilization facility is this sandwich of drainage insulation and loading.

Q I don't understand yet. The white band is the thawed area, is it?

A Yes, the top of the ground is here, this is the top of the peat.

Q And you're indicating above the peat?

A And above the peat would be placed on top, yes.

Q Yes. Now, what is the

first layer above the peat?

A This would be a drainage layer to allow the water that is coming out due to thaw, to be carried away.

Q Yes. Now, what is the depth of the drainage layer?

A Oh, the order of a foot or so.

Q Yes, and that would be gravel?

A Sand, gravel, depending on design.

Q Yes, now what is the dotted line? Is that the condition of the two?

A No, it is a layer of insulation that would be calculated and placed within the sandwich, if the design indicates that retardation of the rate of thaw is helpful.

Q I see. What would the insulating material be?

A It would depend upon where you are. It might be prudent to use wood chips if there's a lot of wood around that you want to dispose of, but likely it would be a few inches of styrofoam.

Q Yes, I see. Now, what is the next layer above the insulation?

A It is a granular cap whose role is to put load on the sliding surface, or potential sliding surface down here, and it would also be granular material.

Q When you say granular material, is that gravel?

A Sand or gravel.

Q Yes. And what depth would it be?

A It would be, the depths would be calculated as a function of the slope and design requirements, in the order of a few feet.

Q Yes, I take it that the depth of each of those layers has to reflect and respond to the problem that the slope presents under analysis?

A Yes. The rather interesting feature that if you try to stabilize with just the surcharge, you need quite large amounts. If you try to stabilize with just insulation, you need quite large amounts.

The analysis shows how the use of the two optimizes and you get a very efficient compact sandwich to stabilize.

Q Now, in terms of that technique which you've explained for me, what is the degree of slope or the range of slopes to which it would be appropriate, or is it a general purpose remedy?

A Oh, it would be -- it's a general purpose wherever planar slides, planar slides associated with thawing are identified, so we're thinking here more gentle slopes perhaps in the finer grained materials.

Q What sort of degree are you thinking of?

A Six, eight degree type of slope. I don't think our three degree slopes are going to prove to be unstable.

Q I see. Now, what about slopes of more substantial gradient than that?

A These are mainly in approaches into valleys and I think that the technique might have some application there, but buttressing might be more appropriate there.

For example, the Great Bear is a case in point, you think of buttress as the right approach.

Q Yes. Well, if the buttress were not elected as the remedy of choice, to what grade can you apply this mechanism?

A About, considering the worst soils that exist in the Mackenzie Valley, if you are thinking of the finer grained soils, around 10 or 12 degrees.

THE COMMISSIONER: Dr. Morgenstern, on the diagram that you just showed us, the word vegetation appeared, and until you explained the diagram, I thought that was the topmost layer. Did you say that there was to be a layer of vegetation on top of the --

A I did not, but these will be revegetated. We're advised by the biologists that the depth that we think might be used are suitable

to establish revegation. Of course, in the long run, that will contribute but for a short term problem that has not been considered.

MR. SCOTT:

Q I take it, Dr. Morgenstern, that revegetation would (a) perhaps be inevitable, and (b) desirable in terms of stability?

A Yes.

Q And I take it that not shown in the diagram except perhaps as a line, you would want to add another layer which would be a more suitable revegetation medium than sand and gravel?

A Well, it would be part of the upper zoning. It would be designed or composed in such a way that vegetatation can be established.

Q So it would not only be sand and gravel? What would the top layer be then?

A Whatever our vegetation people need to establish vegetation.

Q Yes.

A I can't give you a composition here.

THE COMMISSIONER: Could I ask a question, Mr. Scott?

Q The usefulness of revegetation, assuming it were merely seeding of grass, the usefulness of that from the point of view of slope stability would be very, very limited, wouldn't it?

A Yes, this is only a

reconstructing or attempting to reconstruct the environment, yes. We are not relying on that vegetation.

Q No, no and since in many parts of the right-of-way, you will be clearing the ground of tree cover, there is no slightest possibility of achieving restoration except over a period of many, many, many years?

A Yes, that's right.

MR. SCOTT:

Q Mr. Williams, would you agree with me that most experienced contractors are not very happy with the prospect of having to place thinly layered blankets on slopes?

WITNESS WILLIAMS:

A If they were paid for it, I think they would be glad to do it, Mr. Scott.

Q Well that puts you and I in the same camp on a lot of these issues, but I take it that --

THE COMMISSIONER: You are both men of the world, obviously.

MR. SCOTT: I was going to say, Mr. Commissioner, that we were both mercenary.

Q Mr. Williams, I understand that contractors, like lawyers, will do what they are told, but wouldn't you agree with me that for an experienced contractor, it's not a happy prospect because of the difficulties involved?

Well don't ask an inexperienced contractor.

A I don't know, Mr. Scott. If you're getting into the type of the contract that might be used on this project, I don't think you want to get into that at this time, but the contractor -- any contractor would be glad to do what he's paid for.

Now, if he has a contract and this isn't included, and you tell him that this has to be done within his price, certainly he would be unhappy to do that, but --

Q I'm not referring to the contractual obligation at all. I'm suggesting to you that sitting around in a construction engineer's club or wherever experienced construction men meet, they would commiserate, one with the other, with the problems involved in placing thinly layered blankets of differing materials in appropriate proportions on slopes?

A A part time contractor might take this attitude. A landscaping contractor may think it's fine.

Q Well for a landscape gardener, I think there might be no problem, but you're not in that business, are you?

A No sir, I'm not.

Q The diagram suggests you may get into it.

MR. GENEST: Do you commiserate with other lawyers when you get a hard case?

MR. SCOTT: I sympathize with your difficulties, Mr. Genest.

THE COMMISSIONER: You walked into that one.

MR. SCOTT:

Q I want to read you a paragraph from the Northern Engineering Services report on slope stability in permafrost terrain, the white volume of December, '74. It's in the construction notes --

WITNESS MORGENSTERN:

A Page number, please?

MR. SCOTT: We noted the page numbers, and it happens to be one of your bigger reports. I can fill in the time by criticizing the index, Mr. Genest, but I won't.

MR. GENEST: I am grateful for small mercies.

MR. SCOTT: It is at page 74, and it's paragraph 4, it's called:

"Construction notes on stabilization."

I might just read the paragraph:

"It is anticipated that there will be slopes that are considered marginally stable in the skin flow failure mode, and will require the application of preventive stabilization schemes in order to ensure stability,"

and stopping there, Dr. Morgenstern, that's one of the things we've been talking about?

A Yes, exactly.

Q

"However, at this time it is inappropriate to become specific as to the exact configurations that these remedial measures would entail and how many slopes would require treatment of one form or another."

Now there's no doubt about that, is there?

A No.

Q

"This is primarily because there is a lack of design input parameters on which to base

typical designs. While designs could be formulated at this time, on the basis of conservatively assessed parameters and judgment, it is not considered appropriate to do so. The finalization of economically expedient and environmentally suitable stabilization schemes will require close liaisson and discussion with geotechnical, geothermal, environmental, and construction support groups."

Would it be fair to say that that summarizes the problem to which I've been attempting to allude?

A I really don't see that as a problem, Mr. Scott. It's a reality. This is the state of development of this project. What this is alluding to is that environmental and expedient construction procedures and so on will be integrated on a mile-by-mile design.

Q Let me ask you this. What design input parameters are presently required so that typical designs can be made?

A If we were to have to design at this instant in time for final construction, we would be designing on the worst soils we know, so that the further input parameters have to do with more site specific sampling and testing from actual slopes that have been identified in order to not needlessly waste these procedures.

Q Well now, let us suppose

that in spite of your best attempts to avoid unstable slopes by route selection, and your best attempts to prevent stabilization as a result of your designs, a slope failure of one type or another does in fact occur?

A Yes.

Q I take it that then you're in a remedial situation?

A Yes.

Q Not only to remedy whatever damage may have in the course been done, but also in certain cases to prevent recurrence?

A Certainly.

Q Now I gather that in that situation there will be some kinds of schemes that will be applicable to failed slopes or slopes that are in the course of failing, and will be used for the prevention of instability?

A Yes.

Q And the actual procedures that will be required to do the remedial slope, the remedial work after the failure or during the course of failure, although known in concept, are not yet worked out?

A They would rely on similar procedures that are used at the outset. The slope may have been not identified as unstable, so that these schemes would be applied. There are other alternatives, one might come in to freeze some material

and put on surcharges and gravel berms and things like that. There are a variety of remedial schemes that are in our armory.

Q When you say "in our armory", I take it you mean in your armory of conceptual designs?

A Yes.

Q Yes.

A And experience, of people that have stabilized slopes. After all, these would all be thawed materials, we would be almost back to conventional work to some degree.

Q I take it that the novelty of that situation is not that the materials are thawed, which is common elsewhere in the world, but that they are thawed materials that are moving or have moved on a frozen slope?

A Yes, we would have two problems, to stabilize the thawed material and to stop further degradation of the frozen material.

Q Yes, and whatever the techniques may be in this kind of remedy situation, no matter how widely they have been used in other parts of the world and on the Alaska route and the Dempster Highway, I take it that relatively little is known about their in-site application in permafrost terrain?

A Certainly the experience of stabilizing slopes in permafrost terrain is less

than in non-permafrost terrain.

Q Is what?

A Is less than in non-permafrost terrain.

Q Well now, I take it it is reasonably obvious even to me from what you have said in your remarks at the beginning of the panel, that the prediction of hazard in slopes and the design of stabilization techniques is going to require a great deal of specific geotechnical information about local conditions on slopes on the route?

A Or at least groups of slopes in certain physiographic or terrain types.

Q Yes. Well, I'd like to ask Doctor, I take it it is your view that the slopes will be analyzed in groups or categories?

A Some will be analyzed singularly; some will be analyzed in groups. I don't think I would expect to have to drill all of the 700 slopes that so far have been isolated in the listing again.

Q Well let me ask you this: Which slopes will be individually examined?

A Those --

Q For geotechnical data?

A Certainly the steeper, and the steeper and the higher slopes, the ones in the more difficult terrain types, the ones that on preliminary calculation have marginal factors of

safety, and which we want to go and evaluate just what materials are, what the analysis is in more detail. These are the slopes that might intrude into an environmentally sensitive area, the slopes that might generate, if they moved would generate erosion problems. These spectrums of considerations will all be employed to pick out the slopes that are worthy of site specific drilling.

Q So am I clear that what you will do is you will pick out slopes that require individual treatment, and then on a group basis or group bases analyze various categories of other slopes?

A Yes, and that grouping will be our function of our knowledge of the terrain conditions. At some locations we will feel that we have pretty good knowledge, and others we feel that our knowledge is poor and we'll have to go and get more data.

Q Yes, and the technique is not only observation but drill?

A Yes.

Q Now, Dr. Clark, I raised this approach to the question with Dr. Morgenstern, who told us, as I understand his evidence, that some slopes will be examined on an individual basis and others will be examined in groups. Before I come to that, perhaps I should ask Dr. Morgenstern, how would you characterize the slopes that you

propose to individually assess? Is it ones that appear to be marginally stable, or marginally instable?

A Marginally -- certainly all unstable slopes. Well, not necessarily. The marginally stable ones, the high steep ones, the ones where sliding of fine-grained material into rivers might change water qualities, and also it will depend upon our knowledge of the ground conditions. Some terrain units we have a fair amount of knowledge and in other terrain units, less knowledge. So that the evaluation of the allowable stress level of a slope is a function of the degree of knowledge, so all of these are really just repeating.

Q So would I be correct in suggesting that you would want, in order to achieve environmental and pipe security, to investigate all slopes that are identified as marginally stable?

A No, I think that we could recommend some stabilization measures on a conservative basis for many of them, and not proceed with further investigation. The further investigation would be to produce more efficient stabilization schemes, or eliminate it.

Q Well, Dr. Clark, in response to request No. 19, which is at page 19 of the book, 19-4, you say -- have you got it?

WITNESS CLARK: I'm just getting it, Mr. Scott.

THE COMMISSIONER: What was

that again, 19?

MR. SCOTT: 19-4, Mr. Commissioner, about half-way through the first paragraph you say:

> "All slopes identified as being marginally stable will then be investigated by instrument surveying and drilling. The location number and depth of the drill holes, the frequency and type of samples recovered and the extent of laboratory testing to classify the soil and measure soil parameters will vary and will depend on the particular conditions at each slope."

Now what I'm really anxious to know is, is the applicant adopting the view of Dr. Morgenstern, as I understood it to be, or may we assume that in fact a more conservative approach will be utilized so that all slopes that are marginally stable will be individually examined?

WITNESS CLARK: All slopes that are considered marginally stable in this sense would indicate that certain investigation has preceded that classification. A final classification of those that are going to be required for a more intensive investigation; for example at this time we have field programs going that are looking at slopes that have failed and slopes that one might have thought they should have failed under the physical conditions, and these will give us a further

characterization of slopes in general. We would then have a reconnaissance and a number of features could go into that, that will determine those that require final design detail.'

Q What I want to know is the position of the applicant for the purposes of this inquiry. Is it a correct statement at this stage to say that it is your intention that all slopes identified as being marginally stable, will be investigated by instrument surveying and drilling?

A When we have reached that point in time where we are ready to initiate the field drilling program,or field seismic survey or instrumentation, we will have a classification of all slopes that are marginally unstable, but they would not include all the slopes, 700 slopes or so that we've listed.

Q I understand that, but do I have your assurance that the applicant's position is that all slopes that are marginally stable or judged by it to be marginally stable, will be examined by drilling?

A I am not sure that we are not talking along two different lines. All slopes will be examined, there may be a group of slopes with very similar characteristics where representative or worst casing may be drilled and applied to the others.

Q Well then,I take it that the statement that is contained there is not your present intention?

A No.

MR. GENEST: Well no, that to me, is not a proper statement of --

MR. SCOTT: How does Mr. Genest read that sentence?

MR. GENEST: I think it was not a question of the time of identification of an unstable slope.

MR. SCOTT: Well, we have Dr. Morgenstern's view and that doesn't cause me any difficulty whatever, as to how he would propose to do it. I think it's been clear and it is evident the way that he would approach the problem.

I'm concerned about the response to the questions. Now, is that an accurate statement? If it's not, I'm not saying that one is preferable to the other, I don't know, but I want to know what the intention of the applicant is?

WITNESS MORGENSTERN:

A Could I try and reconcile, perhaps two different sources of information. We have a table of potentially unstable slopes that have been selected on a very conservative point of view. Of that, for example, there are 340 some odd slopes very gentle inclincation, 3 to 6 degrees, zero to forty feet in height.

Our present view is each of these slopes worthy of individual consideration from a design, analysis, a judgment point of view, but I would not anticipate drilling 344 gentle little slopes,

On the other hand, when we have gone through the design, and we then are left even after implementing a remedial measure or a preliminary remedial measure and are still left with a

degree of stress mobilization that we think is marginal, marginal for security, we would then go out and get much more information for each of those cases.

Q Without carrying on unduly, you have listed in Table 1.2-1, 686 slopes that are regarded as potentially unstable slopes along the right-of-way.

I read the response to the Assessment Group as assurance that all slopes identified as being marginally stable will then be investigated by instrument surveying and drilling.

MR. GENEST:

A Mr. Scott, I think --

MR. SCOTT:

Q You think that is not correct?

A No, the distinction that I tried to draw to your attention here is that this heading is potentially unstable slopes. These will now be refined, and we will end up from this 686 with still, after our preliminary design work, some marginally unstable slopes.

I said marginally stable slopes, we'll not have any unstable slopes.

Q Right. And I take it at the moment, are you in a position to say -- I take it you're not in a position to say how many they will number, at this time?

A No, but I anticipate they will be numerous. There will certainly be quite a few slopes that will be drilled.

THE COMMISSIONER: I wonder,

I'm not quite sure where -- could you summarize what you understand to be the effect of what has just been said, Mr. Scott, for my benefit?

MR. SCOTT: Well, Mr. Commissioner, I think the dialogue began by Dr. Morgenstern explaining the approach to the problem, that is, as I understood him to say, that there would be some slopes that would require individual attention, and some that could be attended to, if I can put it that way, in classifications or groups, for each of which there would be a conservative assessment and a typical model, if I can put it that way, a classification system.

But that not all therefore, would be individually examined. I then put to Dr. Clark, the observation that the Assessment Group's answer indicated that all slopes that were marginally stable would be examined --

MR. GENEST: All slopes identified.

MR. SCOTT: Identified.

MR. GENEST: And the process is that they're identified after the process you've just described has been gone through.

MR. SCOTT: I'm sorry to hear that we have to read the responses with this particularity. I may not understand it, but I obviously, according to the rationalization now developed, have misread that sentence, and I take it that the process is that the 686 potentially unstable slopes are not

the same as slopes that are mar ginally stable, and that of those 686 potentially unstable, there is to be a break-out of some that are marginally stable.

Q And do I understand that those will be individually attended to?

A Yes, the -- if I can do again -- of the 686 slopes, the further analysis will identify some that are clearly very stable, and it will identify some that are clearly unstable, and they will be made stable, and we will identify some that are marginally stable, and they will either be made stable, much more stable, to take it out of that marginal classification, or they will justify individual attention in order to -- in order to fine tune the design.

THE COMMISSIONER: Well ,that leaves me with only one figure that remains unaccounted for, 340 slopes. I must have lost the significance of that.

MR. SCOTT: 344, Mr. Commissioner- is I think the precise figure which Dr. Morgenstern was referring to and is the total number of slopes which have a 3 to 6 degree angle. Have I read the chart correctly?

A And a zero to forty foot height.

Q Yes, and I think -- and a zero to forty foot height, and I think Dr. Morgen- stern's point was that insofar as they are relatively minor, they might not -- they would probably not be

among the ones generally that would require individual treatment?

A We expect the vast number of these to end up being judged stable.

THE COMMISSIONER: Well, going back to the chart that you had on the board here two or three weeks ago, do -- you said then that all of the slopes of a certain height and more than three degrees, would -- all of those together came to your 686?

A Yes.

Q So you're taking the lowest category, so to speak --

A Yes.

Q -- of potentially unstable slopes, and those are the 344 slopes that you expect that many of those will not have to be examined individually?

A They will have to be examined individually in the office, but I don't expect they'll have to be drilled.

THE COMMISSIONER: Yes, all right, I'm with you.

MR. SCOTT: Well, Mr. Commissioner, I plead guilty to not apprehending the rationalization. I was unable to distinguish between potentially unstable slopes and slopes that are marginally stable. I now have that evidence.

THE COMMISSIONER: Well --

MR. SCOTT: They're obviously

not the same and they may, in the view of the --

THE COMMISSIONER: Marginally stable slopes are stabler than potentially unstable slopes, or maybe they are not.

MR. SCOTT: One would have thought so, but they are included among potentially unstable slopes.

THE COMMISSIONER: I think I understand this anyway.

MR. SCOTT:

Q We had better begin to read in detail the replies to the Assessment Group.

The response, Dr. Morgenstern, to the Assessment Group question, and I hope it's one that I can understand this time on monitoring, deals with -- and I take it stopping right there, monitoring generally speaking, is the process that will occur after construction ?

A Yes.

Q Yes. It's question 55. And it deals, without reading it, "with various techniques for providing for early detection of signs of instability or potential instability of slopes" on page 1 and 2, and the first sentence of the statement, in paragraph (a) on page 55.1 is this:

"Long term instrument monitoring will be considered for all slopes which could affect or be affected by the pipeline or that have some condition that

could change during the life of the pipeline to reduce the margin of safety against failure".

The margin of safety begins to sound very like Dr. Casagrande , but I'll leave that for the moment.

THE COMMISSIONER: Which one is that again, I'm sorry?

MR. SCOTT: It's page 55-1, under sub-paragraph (a).

MR. GENEST: The bottom of the page, sir.

Q And I read the first sentence. Dr. Morgenstern, can you tell us how you will decide which slopes to monitor?

A The slopes that have the largest potential for movement would normally be in the less stable soils, the steeper slopes, the higher slopes, perhaps a slope where there is a potential for dramatic river change which could induce toe erosion.

Q I would agree that those are definitely the slopes you would want to monitor. What I'm really asking is how will you decide which those are and designate them? Has that been done or will it be done?

A That will be a mile by mile function to evaluate .

Q By what process is the determination made?

A It would be -- particular slopes would be flagged during the analysis process when we're sorting out these potentially unstable slopes. We will look at the configuration, we will see whether we have -- whether it's a rather unique type of slope or whether it's a very common type of slope, whether we have more experience with it or less experience, whether the implications of movement are more severe or less severe and so on.

Q And would you agree with me that your monitoring list will rely very heavily

on the actual construction experience as the pipeline moves through the valley?

A We will certainly get a great deal of information from that, no doubt, but the final details of the instrumentation will be greatly assisted by the construction experience.

Q Yes, so that one would hope to have the complete and best list of slopes to be monitored, not before but rather after construction.

A Yes, certainly.

Q Now what in view of that answer, it will be difficult, but what is your present estimate of the number of slopes that you may want to monitor? Let us say out of the 686.

A I would suggest it's measured in tens as opposed to hundreds.

THE COMMISSIONER: Well, somewhere between 1 and 10, or between 1 and 100?

A Tens, it would be greater than ten and less than 100. I can't do better than that.

Q You told us the various aspects of the passage of man, by which I include construction, can increase the instability of slopes from time to time.

A Yes.

Q And I take it that in this context the kinds of things that have the potential for increasing instability are such things

vegetation removal and disturbance of the organic mat, backfilling of the pipeline ditch on slopes --

A Well, that's a feature that's been designed and has to be considered. It's a design consideration.

Q Yes, but it is something that has to be watched because potentially it may in certain circumstances increase instability.

A It may become unstable, the backfill, certainly.

Q And cuts on slopes can also increase instability.

A Yes.

Q Are there any other factors, any other factors of construction that occur to you at the moment that can increase instability?

A Disruption of drainage.

Q Yes.

A These are the main ones.

Q I'm sorry?

A These are the main ones. Poor placement of spoil, building large piles where they shouldn't be built.

Q Can the improper or imprudent use of equipment increase instability?

A Yes, if for example an operator drops his bulldozer blade when he shouldn't drop his bulldozer blade and strip the organic cover, there is no question that that will aggravate thaw

and increase instability.

Q And I take it that in terms of construction techniques, it may be a significant factor in dealing with slope instability to select one mode rather than another of construction.

A I can't --

Q Well, for example, it might as I think Mr. Williams suggested when we were looking at photographs yesterday, it might be desirable in certain locations to clear trees on a by hand basis rather than sending in some gigantic bulldozer on a slope.

A Generally speaking, the construction practice being adopted in this project is very impressive in its contribution to minimizing slope stability problems, thermal degradation problems, for example in contrast to what is my experience in the Alaskan Pipeline project.

Q Yes, but I take it that that experience indicates that the selection of techniques of construction is frequently a dominant consideration.

A This project has selected techniques from that consideration. Be more specific.

Q I'm sorry, a construction engineer has various techniques by which various tasks can be performed.

A Yes.

Q I'm putting it to you that in certain cases, looking at slope instability

it can be critical which of the various techniques to do the given job he selects.

A It can contribute, and I think that this was part of the thrust in this report, to illustrate the need for geotechnical and environmental construction people to collaborate in the fine tuning of their procedures.

The reliance on snow and ice roads is a major contribution in this regard.

Q Well now, in the responses, question 24, page 2, which is the section on buried versus elevated pipeline --

MR. GENEST: 24?

MR. SCOTT: 24-2, referring to the first full paragraph on that page, the last sentence:

"Applicant does not expect that slope conditions which would preclude the burial mode will be encountered, since potential problems can be solved either by re-routing or slope stabilization."

Can you visualize any situation where you would recommend pile construction on a slope because of slope failure hazard to either the pipeline or to the environment ?

A No. The support, the frozen ground around the pipe contributes quite a lot to its own integrity, and I can't at this time think of any pile mode that would be intrinsically

safer from that point of view.

Q Well now, in what way, if any, will the chilling of the pipeline affect the stability of slopes, and that's really what I think you've just referred to?

A Thawed ground is less stable than frozen ground, and so that the encasement of the pipe itself in frozen ground makes that component stable on the slope, while the right-of-way itself might be unstable when it's thawing.

Q Can you envisage situations in which the chilling would lead to increased instability as a result of drainage problems?

A Yes.

Q How would you propose to combat those?

A By drainage or by putting gravel filters on the uphill side. These are measures we have under consideration.

Q Well, you say "by drainage". Are you --

A Artificial drainage, putting in conduits, little pipes on the uphill side or by putting gravel filters on the uphill side to allow the water to --

Q Are you referring to the kind of drainage techniques that Dr. Clark referred to, berm breaks?

A No, no. The configura-

tion that I have in mind is the frost bulb impeding flow through unfrozen ground on sloping ground. This builds up water pressure in the sloping ground uphill of the frost bulb, and aggravates stability, tends to make that material want to slide and sheer more than it might otherwise do. This is uphill of the pipe. In order then to return that material to its previous degree of stability, one has to reduce the water pressures by drainage, by putting in horizontal pipes or digging little trenches up the hill, or by putting a gravel cap which would allow the water to come out without bringing the organics down.

Q And I take it that this maybe in addition to the berm break--

A Yes.

Q -- through the bulb solution that Dr. Clark spoke of.

A Yes, that's right.

Q And would these remedial measures be, if not permanent, long-term?

A Yes.

Q And what actual ground experience is there in dealing with these techniques in permafrost terrain?

A The soil that we're now stabilizing is unfrozen soils. The problem is only serious in the discontinuous zone where we are blocking off flow in thick components of unfrozen soil, so that the principles are just an extrapolation from our

southerly experience.

Q Yes, with the addition that these unfrozen soils again are founded on a permafrost base.

A Yes, I don't think that matters a great deal. We're stabilizing unfrozen soil, either a very thick active layer, or material that's completely thawed. There may or may not be permafrost around it.

Q Whether it is important or not, I take it that there is limited experience in utilizing these solutions in a permafrost situation, that is in a permafrost terrain.

A The problem is only severe where the presence of permafrost is slight. It is actually most severe when it's absent, or possibly more severe when it's absent. So we are borderline as to whether we have a lot of experience in an Arctic environment or not. In my view, it's a natural extrapolation from southern techniques northward.

Q Well we have a lot of experience digging basements in the south, but that's going to cause us a little trouble in Inuvik, isn't it?

WITNESS HARDY:

A There is experience, Mr. Scott on the Westcoast Transmission.

Q Is that the Pointed Mountain line again?

A Another one.

Q That's another one?

Dr. Morgenstern, can you visualize any situation, either engineering or environmental in nature, in which in your judgment it might be proven to relocate the pipe or a pipeline facility, such as the compressor station, after the commencement of clearing or construction in order to avoid a slope that has developed a failure, or that is threatening to fail?

WITNESS MORGENSTERN:

A I can't think of any configuration. We're devoting a great deal of energy to getting it right before construction. The only thing that comes to mind is if we make a mistake.

Q Well, perhaps I can give you an example. I'm advised that it was necessary to relocate the Mackenzie Highway on which perhaps a mistake or two has been made, at the Martin River near Fort Simpson, because after the clearing and

construction had taken place, it was found that there was a tendency to permafrost induced flow landslides, and as a result, the work of clearing and some of the construction had commenced and it was decided, I presume for mixed environmental or engineering reasons that the route should be moved. Can you envisage any situation in which that might happen with respect to this pipeline?

A The procedure that we have described, the documentation in support of the approach to slope stability, I think would have identified the Martin River problem for the Mackenzie Highway people, and it would have been addressed in a more positive manner.

That configuration is anticipated, and we feel that we have anticipated all the configurations, but we may be wrong. The Mackenzie Highway could perhaps have drawn on other advice than they did.

Q Well at least perhaps we have come that far since your examination in chief. You've anticipated all the configurations, but you might be wrong.

Mr. Commissioner, that frankly is all I am prepared to deal with now. I --

THE COMMISSIONER: That's hard to believe.

If you are suggesting we adjourn, I take it that you want this panel back again on Monday, Mr. Scott?

MR. SCOTT: Yes, and I think Mr. Genest wants them back. I won't be held entirely responsible.

THE COMMISSIONER: All right.

MR. GENEST:

They will be glad to be back, they like this place.

THE COMMISSIONER:

They are part of the scenery now.

Well, we will adjourn til 1 o'clock Monday?

MR. SCOTT: Yes, sir.

(PROCEEDINGS ADJOURNED TO 1:00 P.M. ON MONDAY, APRIL 14TH, 1975)